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PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

C. J. VAN DER KLAAUW

N.V. NOORD-HOLLANDSCHE UITGEVERS MAATSCHAPPIJ
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INTRODUCTION

The subject of the projections, deepenings and undulations of the surface of the skull [1]) in relation to the attachment of head-muscles has hardly been examined by zoologists, and it has certainly not been subjected to a consideration through all groups of the Vertebrata. In the past flourishing period of zootomy, the zoologists, in so far as they were anatomists, were really only interested in comparative anatomy, in the sense of the investigation into the features of the conservative characters of elements or into the features of the conservative characters of building-stones of the structure, or, in other words, the investigation into such features of the structure as are peculiar to and characteristic of the representatives of a smaller or larger systematic group. The means of attachment of the muscles to the skull, however, do not belong to these so-called conservative characters of elements of the structure. Moreover, comparative anatomy of the muscular system was given little attention in comparison to that of other organ systems.

In the investigations in the field of the functional anatomy, the ecological morphology and the architectural or structural morphology of skull and head there are also other anatomic facts that attract attention; among these there is the question about the relation between the projections, deepenings and undulations of the surface of the skull and the attachment of muscles [2]).

By projections, deepenings and undulations we understand those features of the surface — like cristae, spinae, sulci, *etc.* — which in the first place are small in comparison with the entire surface of the skull and in the second place constitute details of shape of the general shape or contour of larger units of the surface carrying these features of the surface.

These larger units of the carrying surface occur in the skull in two main forms.

In the first place we mention the large carrying surfaces on or in the skull, the surfaces of which deviate in position from those of the adjacent surfaces of the skull.

In the second place we have to state as larger unit of the surface that in a few cases the skull as a whole shows a uniformly shaped surface, as is the case with conical skulls of animals with a stream-lined body-outline, and with skulls of burrowing animals.

The area or the places of attachment of head-muscles constitute the

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[1]) DULLEMEIJER, 1951, p. 247 uses skull sculpture as a term in common for projections, deepenings and undulations of the surface, but this seems linguistically less correct.

[2]) For a preliminary report see VAN DER KLAAUW, 1956.

outer or inner surface of so-called functional components of the skull, as I defined them in previous papers (VAN DER KLAAUW, 1941, pp. 245, 250; 1945, pp. 16, 31, 32, 35/36; 1947, pp. 269, 276; 1948b, pp. 1-3).

As a rule, though not always, the above-mentioned large carrying surfaces (surfaces carrying the projections, deepenings and undulations of the surface, at all events those carrying the areas or the places of attachment of head-muscles) and the adjacent surfaces also constitute the outer or inner surface of so-called functional components. There are two important differences between such a carrying surface and a functional component, as I defined it previously. The first difference is that in this article the surface of the skull is at issue, while functional components are spatial components. The second difference is that in the exposition given in my previous paper, functional components were mentioned only (they are represented by areas of attachment of muscles and by the adjacent surfaces, not by small projections), while in this article the carrying surface of the place of attachment for muscles is considered (this is independent of the question whether it is the surface of a functional component or not).

In all these cases with functional component an element of the skull is meant. Objections can be made against limiting the notion of functional component to the skeleton; they have been made by DULLEMEIJER (1956a, pp. 2, 103, 104, 105; 1956b, pp. 388, 489, 490, 491). He remarks that generally the functional components are not restricted to the skeletal parts, but embrace the weak parts too. The functional component in the sense as meant by DULLEMEIJER, (term reserved by him for a general terminology) can be a great apparatus or a smaller construction. An element of these functional components at these different levels can be the skeleton. The skeletal elements of these functional components can be integrated to a whole. In some cases the skeletal elements are not integrated. Outside the skeleton the elements of the same kind in different constructions are very loosely correlated, whereas they are highly dependent on the functional components, which are closely correlated. Much in this field depends on the level on which the functional components are distinguished (DULLEMEIJER, 1956a, pp. 2-3, 103-104, 107; 1956b, pp. 388-389, 489-490, 493).

The functional components in which functions are realized in structure, can be subdivided in smaller functional components or apparatuses, in just the same way as the functions can be subdivided (DULLEMEIJER, 1959, p. 971).

It has been remarked by DULLEMEIJER (1959, p. 970) that the functional components are to be considered centres where in substance certain functions are exercised, or as it were centres of condensation of realized functions, the importance of this functional component gradually diminishing around the centre.

In our inquiry into the relation between the projections, deepenings and undulations of the surface of the skull and the attachment of head-muscles, we may ask ourselves what can be said about it in:

(I) descriptive-anatomic respect;
(II) topographic-anatomic respect;
(III) ontogenetic respect;
(IV) functional-anatomic respect;
(V) ecologic-morphologic respect;
(VI) architectural-morphologic or structural-morphologic respect;
(VII) phylogenetic respect.

As we discussed above, there is little or nothing to be said about our subject from the aspect of comparative anatomy of the features of conservative characters of the building-stones. We know, however, that in the above respects I) up to and including VII) the relation between the projections, deepenings and undulations of the surface of the skull and the attachment of muscles is a most fruitful field of investigation.

CHAPTER (I)

DESCRIPTIVE-ANATOMICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

(I) (i) *Introduction*

This relation under consideration between details of the surface of the skull and the attachment of muscles, confines our interest to those muscles which lie entirely or partly in the head, so far as they are at least at one end entirely or partly attached to the skull. This one end of the muscles can be partly attached to soft parts of the head. The other end is attached either entirely to the skull (or partly), or entirely to soft parts of the head, or entirely (or partly) to skeletal elements of the body outside the head, or entirely to soft parts of the body outside the head.

The examination of the relation under consideration with the above-mentioned restriction, supplies us with the description of all existing conditions in this field, which in some subjective way or other can be arranged into a synopsis.

Considering the present stage of the investigation, at all events with the many detailed questions as examined by my former scholars at Leiden University, an enumeration of the conditions that we actually know in this field, does not appear very important.

It does appear important indeed to count up the general conditions which occur and which are conceivable:

(1) with respect to the way of attachment of muscles to the skull;
(2) with respect to the forms of the projections, deepenings and undulations of the surface of the skull;
(3) with respect to the course of the muscle fibres;
(4) with respect to the parallel or non-parallel position of the surfaces carrying the places of attachment of muscles;
(5) with respect to the opposite or non-opposite position of the surfaces carrying the places of attachment of the muscles.

On the ground of these general conditions which are conceivable, it appears important to sum up the theoretically conceivable combinations, since they can guide us in the examination. This may further give us an insight into the question, which of the theoretically conceivable combinations could also belong to the theoretically possible conditions and which of them have actually been realized.

(I) (ii) *"Standard" conditions*

In order to come to a synopsis in the fields mentioned, it will be useful to establish one special or a few special conditions as a standard first, and to discuss the deviations from this standard not until after that.

We will establish as a standard the following number of special conditions, *viz.:*

(1) concerning the way of attachment of muscles to the skull, we establish as a standard three main forms with two groups of deviations,

(2) concerning the form of the places of attachment of muscles to the skull, we establish as a standard three main forms,

(3) concerning the course of the muscle fibres we establish as a standard one condition, further

(4) concerning the position of the surfaces carrying the places of attachment of the muscles, we establish as a standard one condition, and lastly

(5) regarding the relative positions of the surfaces carrying the places of attachment of the muscles, we establish as a standard one special condition.

(sub 1) Concerning the way of attachment of muscles to the skull, the facts we know about this attachment lead us to establish three main forms as a standard, *viz.* the musculous attachment, the attachment by means of an internal aponeurosis and the one by means of an external aponeurosis.

The distinction between musculous attachment and tendinous or aponeurotic attachment arose from macroscopic anatomy, at all events from macroscopical investigations. This, however, does not mean that even in broad and thick muscles with an extensive area of attachment it is always clear whether the way of attachment is musculous or aponeurotic.

Examples: (1) In the area of attachment of the muscle fibres of the musculus complexus to the "crista occipitalis" in *Phasianus colchicus* L. much connective tissue is mixed with these muscle fibres, especially at the dorsal side of the muscle, where this connective tissue rostralwards passes into the periosteum of the parietale; yet this connective tissue cannot be classed as an aponeurosis (DEN BOER, 1953, p. 341).

If a muscle is very small and very thin, it is not easy to determine the character of the too minute way of attachment for macroscopic investigation. In the case of a very short and very thin intermediate element between the muscle fibres and the skeletal surface, it is impossible to determine with certainty whether this is an aponeurosis (or a tendon) or a musculous attachment. An examination with a magnifying-glass can help us in many cases. An examination with a microscope is of quite a different character. A study of microscopic slides would not have lead as a matter of course to the same distinction (musculous as opposed to aponeurotic). Very probably this would have led to another view on the character of the connection between the muscle fibres and the surface layer of the skeleton.

The fact, that in this article we will take the macroscopic investigation as a basis and not the microscopical structure, entails that we consider as internal aponeuroses all those aponeuroses that bear muscle fibres on both surfaces, also if these muscle fibres belong to different muscles or branches of a muscle, also if they show a different way of attachment *etc.* of its muscle fibres on or in the aponeurosis *etc.* We will call internal aponeuroses those aponeuroses which bear muscle fibres on the two surfaces, also if these muscle fibres are different in character, in number, in the way of attachment, *etc.* The authors (their articles are cited) call these aberrant muscle fibres secondary muscle fibres. BAMS (1956, pp. 249, 253) mentions the fact that some aponeurose fibres contribute to the formation of the aponeurosis and others are only secondarily attached on this aponeurosis; he states that some aponeurose fibres enter into the aponeurosis and others are fixed upon the aponeurosis only.

If we call simple muscles those consisting of muscle fibres without aponeuroses between them and if we call complex muscles those which possess aponeuroses (see MANGER CATS, 1951, p. 192; VAN DEN ASSEM, 1952, pp. 658, 673; SARKAR, 1960, p. 112), then our first main form with musculous attachment occurs in simple muscles and our second and third main forms with an attachment by means of an internal or of an external aponeurosis occur in complex muscles.

Among all forms of the two sorts of aponeuroses realized in nature we establish as a standard the elongated plate-shaped internal aponeurosis and the elongated groove-shaped, so double-sided, and at both ends open external aponeurosis.

In the case of the elongated plate-shaped internal aponeurosis the muscle fibres are attached to both sides of the aponeurosis; the angles between the muscle fibres and the surface of the aponeurosis are generally equal on both sides at the same place, but at different places of the surface they may be unequal (BURGGRAAF, 1954, p. 292).

In the case of the elongated groove-shaped, so double-sided and at both ends open external aponeurosis, the muscle fibres are attached to the inner surface of the walls on both sides; in the standard condition the angles between the muscle fibres and these two surfaces will be equal.

In connection with the forms of the places of attachment of muscles, settled as a standard, we have to add two groups of deviations from the standards of both of these aponeuroses.

A first group of deviations concerns the length of these aponeuroses. The lengths of the internal and of the external aponeuroses can be greater or smaller. If the length is slight, the plate-shaped internal aponeurosis approaches the form of the cylindrical or cone-shaped internal tendon and the groove-shaped external aponeurosis approaches the form of the V-shaped external tendon (plates 1-16, 19).

A second group of deviations from the above-described standard of the external aponeurosis concerns the shape of its basal part. In the case of the external elongated groove-shaped aponeurosis both walls of the groove can be attached to the surface of the skull, along one line (the standard condition), in the second place both walls show a common basis and thirdly, both walls are apart from each other and with an intervening space (plates 1-16, 19). Similar conditions occur in the case of a V-shaped external tendon.

The above-mentioned three main forms of attachment of muscles which we settled as a standard, the musculous attachment, the elongated plate-shaped internal aponeurosis and the elongated groove-shaped, so double-sided and at both ends open external aponeurosis, can occur singly, but also in combinations of these forms, at each end of the muscle, while these single conditions and combinations may be equal at both muscle-ends, or different. Similar single conditions and combinations occur with the two groups of deviations from the standard external aponeurosis and with the one group of deviations from the standard internal aponeurosis.

(sub 2) Concerning the forms of the places of attachment of muscles to the skull, the facts we know about these places of attachment suggest three main forms of the surface of the skull with its projections, deepenings and undulations in relation to the attachment of muscles, *viz.* a smooth, flat surface of the skull, a crista and a spina which we will settle as a standard. Although the spina could be understood as a crista which according to its longitudinal axis is considerably shortened, we have not done so for special reasons. — The length of both aponeuroses and the shape of the basal part of the external aponeurosis shows a relation with the form of the surface of the skull. We may expect that the standard aponeuroses, *viz.* the plate-shaped internal aponeurosis and the groove-shaped external aponeurosis, as assumed here, which are both distinctly elongated, cannot occur on spinae. On spinae we may expect a cylinder-shaped or cone-shaped internal tendon, or a V-shaped external tendon, therefore, forms which we did not establish as a standard, but which we considered as derivations from it.

(sub 3) Concerning the course of the muscle fibres we take as a standard the condition that firstly the muscle fibres run parallel or nearly parallel to each other and secondly that they are perpendicular to the surfaces carrying the places of muscle-attachment.

(sub 4) Concerning the position of the surfaces carrying the places of attachment of the muscles, we take as a standard such a position in which the surfaces referred to run parallel to each other.

(sub 5) Concerning the relative positions of the surfaces carrying the places of attachment of the muscles, we take as a standard the position in which the surfaces referred to are directly opposite each other.

We will now consider the theoretically conceivable combinations of the standard conditions which we established in respect of the five anatomical characters mentioned. These are in the first place the three standard forms of muscular attachment, the musculous one, the internal aponeurosis and the external aponeurosis with the deviations as to the length and the shape of the basis, as we discussed above. These are in the second place the three standard forms of the places of attachment, *viz.* the smooth, flat surface, the crista and the spina. As to the three other respects in which the conditions of the attachment may occur, we refer to the single standard condition we stated above (see pp. 18, 20 and 21, sub 3, 4 and 5).

In this way we come to six theoretically conceivable combinations (plates 1-3; nos. I to VI inclusive), in which there is one main form of attachment at each muscle-end; we obtain nine theoretically conceivable combinations (plates 4-8; nos. VII to XV inclusive), in which there is one main form of attachment at one muscle-end and two main forms at the other muscle-end; we arrive at three theoretically conceivable combinations (plates 9-10; nos. XVI to XVIII inclusive), in which at one muscle-end there is one main form of attachment and at the other muscle-end all three main forms; six theoretically conceivable combinations (plates 11-13; nos. XIX to XXIV inclusive), in which occur two main forms of attachment at one muscle-end and also at the other muscle-end; three theoretically conceivable combinations (plates 14 and 15; nos. XXV to XXVII inclusive), in which occur two main forms at one muscle-end, and at the other muscle-end all three main forms of muscle-attachment; finally, one theoretically conceivable combination (plate 16; no. XXVIII), in which occur all three main forms of muscle-attachment at both muscle-ends. Consequently there are 28 theoretically conceivable combinations in total.

When we conceive at each muscle-end only one single main form of the surface of the skull settled as a standard (smooth, flat surface; crista; spina) and therefore no combinations of two or three of these main forms at one muscle-end, and when we conceive the shape of the surface of the skull at both muscle-ends either equal or different, then the 28 theoretically conceivable combinations just mentioned show in total $3 \times 6 + 25 \times 9 = 243$ theoretically conceivable combinations of the attachment of muscles to the surface of the skull (it is only in three groups that the two muscle-ends are equal and so there is only one possibility when the forms of the surface of the skull opposite each other are different).

(I) (iii) *The general conditions with respect to the character of the attachment of the muscles to the surface of the skull*

A consideration of the five different anatomical aspects of this problem, as stated above, gives rise to the following remarks.

(iii) (1) Way of attachment of muscles to the skull

(1) (a) The conditions given by the main forms with their various deviations

We have described above (p. 19) three main forms of attachment, established by us as a standard: the musculous attachment, the attachment by means of an elongated plate-shaped internal aponeurosis and the attachment by means of an elongated groove-shaped, so double-sided, and at both ends open external aponeurosis. — We have also described a first group of deviations concerning the length of the aponeuroses; if the length is slight, the plate-shaped internal aponeurosis approaches the form of the cylindrical or cone-shaped internal tendon and the groove-shaped external aponeurosis approaches the form of the V-shaped external tendon. The second group of deviations described already, concerns the shape of the basal part of the external aponeurosis: both walls can be attached to the surface of the skull along one line, they can show a common basis and they can be separate from each other and with an intervening space.

Besides these standard conditions and the two groups of deviations, nature shows a number of other features which will be discussed now.

For practical reasons we have settled as a standard shape the elongated groove of the external aponeurosis, which is double-sided and open at both ends. As a standard we might as well have fixed the external aponeurosis in the shape of an elongated "tub". From this new-mentioned standard we can derive the groove which is open at both ends by reduction of the two half-funnels. We may also derive the "tub" from the first-mentioned standard of the external aponeurosis, when the two open ends of the double-sided groove-shaped external aponeurosis are closed by an external tendon in the shape of half a funnel (plate 19). This elongated tub-shaped external aponeurosis shows the same two groups of deviations. If the length of this external tub-shaped aponeurosis is slight, it approaches a funnel-shaped external tendon. The elongated tub-shaped external aponeurosis as well as the funnel-shaped external tendon also show the deviations of the basal part. The "tub" can show a basal plate, the "funnel" can show a basal stalk, the basal edge of the wall of the "tub" as well as that of the "funnel" can be attached to the skull apart from each other and with an intervening space. We will not indicate all ways of attachment possible with this form, nor picture them, but confine ourselves to picturing a number of cases of the "tub" (plate 17) and of the "funnel" (plate 18). The first row of figures of both plates illustrate conditions in which the basal edge is attached to the skull along one line, *resp.* one point. The second row illustrates conditions in which there is a common basal plate or stalk, and the third and fourth row depicts conditions in which the wall is attached with an intervening space.

Apart from the two groups of deviations mentioned showing differences in the length of the aponeuroses and in the form of the bottom of the external aponeurosis, the elongated plate-shaped internal aponeurosis, the internal tendon, the elongated groove-shaped external aponeurosis, the V-shaped external tendon, the elongated tub-shaped external aponeurosis and the funnel-shaped external aponeurosis (the last four with the deviation in the form of the basal part) can also show two other groups of deviations: one (the third group) in the development of incisions, the other (the fourth group) in the inclination of the aponeurosis in relation to the carrying surface.

To the third group of deviations belong the incisions in the walls of these six types of aponeuroses with their eight additional forms. There can be one incision or two or more incisions, they can occur in different places, they can show a different breadth, even of half the circumference.

To the fourth group of deviations belong the cases in which the axis of the aponeurosis does not occupy a rectangular position on the carrying surface, but makes a sharp angle, even so sharp that it approaches the tangential condition.

On the basis of these six types of aponeuroses with eight additional types and the deviations of the said third or fourth group we get the following conditions (plate 19) [1]):

a. The internal aponeurosis shows the standard form, *i.e.* of an elongated plate (plate 19, fig. a).

b. The internal aponeurosis shows the form of a cylindrical or cone-shaped internal tendon (plate 19, fig. b).

c. The internal aponeurosis shows a form which is a combination in the sense of a local blending of an elongated plate-shaped internal aponeurosis and a cylindrical or cone-shaped internal tendon (plate 19, fig. c).

d. The internal elongated plate-shaped aponeurosis shows one incision or a number of incisions (plate 19, fig. d).

Examples: (1) The two separated aponeuroses of the musculus rectus capitis superior of *Anas platyrhyncha platyrhyncha* (L.), attached to two separated caudal tuberosities on the basitemporal plane might be considered a plate-shaped internal aponeurosis with a very deep incison (Davids, 1952, p. 537).

[1]) For examples other than those in this list of conditions and in all other cases up to p. 81 see paragraph 6 dealing with examples given at the end of this chapter I on the descriptive-anatomical examination. In these last-mentioned examples only those muscles are collected that are attached to the skull at both muscle-ends. All the other muscles described in the literature cited are given in the text of this chapter I outside paragraph 6 at the end (see also pp. 57, 57/58, 58, 59, 59, 60/61, 61, 64, 81.

e. The internal cylindrical or cone-shaped tendon shows one incision or a number of incisions (plate 19, fig. e).

f. The internal elongated plate-shaped aponeurosis and the internal cylindrical or cone-shaped tendon are not perpendicular to the surface to which they are attached, either directly or by means of a crista or spina, but they make an acute angle with the carrying surface of the skull; this angle may be so small that we may speak of a tangential attachment (plate 19, fig. f). The position of crista and spina in such cases will be discussed later.

Examples of a tangential attachment: (1) The internal aponeuroses of the musculus dorsolateralis in Squaliformes at their places of attachment to the dorsal plane of the regio occipitalis make an angle of about 90° with this surface which slopes backwards and curves downwards to the foramen occipitale. In the first place this is the case with the aponeurosis (a) which is attached along the lateral surface of the rounded ridge over the canalis semicircularis posterior (present in *Scylliorhinus*, not in *Mustelus* and *Squalus*). In the second place, such is the case with the aponeurosis (b) which is attached along the medial surface of that same ridge. In the third place it is the case with the rectilineal aponeuroses of the lateral part of the muscle which with their rostral ends are only attached to the processus postorbitalis; here they are situated obliquely (in *Squalus* these rostral ends run nearly parallel to the skull, having turned nearly 90°), or they are attached along a slight incline in the surface of the skull, as in *Squalus* (MANGER CATS, 1951, pp. 196-199, 299, 300).

(2) The rather long aponeurosis of the musculus levator scapulae inferior in *Rana esculenta* L. is attached tangentially on the cartilage lateral to the parasphenoid, the cartilage being hardened at this place of attachment (COOL, 1952, pp. 642/643).

g. The external aponeurosis shows the standard form, *i.e.* of an elongated groove, so double-sided and open at both sides (plate 19, fig. g).

h. The external groove-shaped aponeurosis shows the form of a V-shaped tendon (plate 19, fig. h).

i. The external elongated groove-shaped aponeurosis which is open at both sides, shows a single aponeurotic plate at the common base of the two walls (plate 19, fig. i).

j. The external V-shaped tendon, which is open at both sides, shows a single aponeurotic plate or stalk at the common base of the two walls (plate 19, fig. j).

k. The external elongated groove-shaped aponeurosis, which is open at both sides, shows two plate-like walls which are implanted separately on the common skeletal carrying surface, *i.e.* with a space in between (plate 19, fig. k).

l. The external V-shaped tendon, which is open at both sides, shows two narrow walls which are implanted separately on the common skeletal carrying surface: with a space in between (plate 19, fig. l).

m. The external elongated groove-shaped aponeurosis shows one incision or a number of incisions on one or both walls (plate 19, fig. m).

n. The external elongated groove-shaped aponeurosis and the external V-shaped tendon show an unequally developed height, owing to a reduction of one of the walls which may go as far as practically a total loss. This reduction could also be considered to be a very deep and very wide incision (plate 19, fig. n).

Such an external aponeurosis with a total loss of one of the walls, can also be called a "surface aponeurosis"; in such a surface aponeurosis the muscle fibres are attached only to one side of the one remaining wall; the angle at which the muscle fibres are attached to the surface of such an aponeurosis is often very small (BURGGRAAF, 1954, p. 292). — In my opinion the definition of surface aponeurosis given by SARKAR (1960, pp. 112-113: "a surface aponeurosis is an aponeurosis where the muscle fibres are attached on one side of the aponeurosis") could include an external aponeurosis with one plate-like wall as well as such an aponeurosis with two plate-like walls.

Examples: (1) The external aponeurosis of the musculus spinalis capitis in *Vipera berus* (L.) on the supraoccipitale is in my opinion an example of such a total loss of one of the walls, as the muscle fibres start from the ventral plane of the aponeurosis; they run to the cervical region (DULLEMEIJER, 1956a, pp. 32-33; 1956b, pp. 418-419).

(2) The external aponeurosis of the musculus longissimus capitis in *Vipera berus* (L.) on the supraoccipitale and the exoccipitale is in my opinion an example of such a total loss of one of the walls, as the muscle fibres start from the ventral plane of the aponeurosis; they run to the cauda (DULLEMEIJER, 1956a, p. 33; 1956b, p. 419; according to 1956a, p. 73, 1956b, p. 459 all cervical muscles possess surface aponeuroses at the skull-end).

(3) The external aponeurosis of the musculus ilio-costalis occipitalis in *Vipera berus* (L.) on the exoccipitalia is in my opinion an example of such a total loss of one of the walls, as the muscle fibres start from the ventral plane of the aponeurosis; they run to the cauda (DULLEMEIJER, 1956a, p. 33; 1956b, p. 419).

(4) The external aponeurosis of the musculus longissimus colli lateralis in *Vipera berus* (L.) on the basisphenoid is in my opinion an example of such a total loss of one of the walls, as the muscle fibres start from the dorsal surface of the aponeurosis; they run caudalwards to the body (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420).

(5) The aponeurosis of the musculus rectus capitis ventralis major in *Vipera berus* (L.) on the basisphenoid is in my opinion perhaps an external aponeurosis with total loss of one of the walls; the muscle fibres run to vertebrae of the cervical region (DULLEMEIJER, 1956a, pp. 34-35; 1956b, pp. 420-421).

(6) The aponeurosis of the musculus rectus capitis ventralis minor in *Vipera berus* (L.) on the processus caudo-lateralis of the transverse crista of the basisphenoid is in my opinion perhaps an external aponeurosis with total loss of one of the walls; these muscle fibres together with those musculously attached to a large area on the caudo-ventrally facing part of the occiput run to the cervical region (DULLEMEIJER, 1956a, pp. 35-36; 1956b, pp. 421-422).

(7) The short aponeurosis of the second part of the musculus spinalis capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., attached to the occipital

wall, is in my opinion very probably an external aponeurosis with a total loss of one of the walls, as the muscle fibres start from the ventral plane of the aponeurosis; this part of the muscle runs to the 9th vertebra; the 1st and 3rd part of this muscle shows a musculous attachment to the occipital wall (DULLEMEIJER, 1959, pp. 909-910).

(8) The aponeurosis of the musculus longissimus capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., attached to the crista occipitalis, is an external aponeurosis which, in my opinion, shows a total loss of one of the walls, as the muscle fibres start from the ventral plane of the aponeurosis close to its end; they run to vertebrae (DULLEMEIJER, 1959, p. 911).

(9) The tendinous attachment of the musculus rectus capitis ventralis major in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., attached to the processus sphenoideus is in my opinion an external aponeurosis, showing a total loss of one of the walls, as the muscle fibres are attached to the dorsal surface of the tendon; they run to the hypapophysei of the 3rd-26th vertebra (DULLEMEIJER, 1959, p. 911).

(10) The short aponeurosis to which a part of the musculus longissimus colli lateralis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., is attached, is in my opinion probably an external aponeurosis showing a total loss of one of the walls, as this aponeurosis is attached to a crest which is formed in the border of the excavation for musculous attachment; the muscle runs to the 3rd-8th vertebra, where sometimes an aponeurotic attachment is formed (DULLEMEIJER, 1959, p. 912).

(11) The aponeurosis to which the musculus complexus in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached is in my opinion probably an external aponeurosis showing a total loss of one of the walls, as this aponeurosis lies close under the aponeurosis of the musculus adductor externus and is almost inseparable from it; for this reason the muscle fibres which arise somewhat backward from this aponeurosis must start from the free surface only; this muscle runs to the 3rd, 4th and 6th vertebra (DULLEMEIJER, 1951, p. 533).

(12) The very small and short aponeurosis which is attached to the very small crista on the processus occipitalis lateralis ossis squamosi, the muscle fibres of the musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) arising from this aponeurosis, is a surface aponeurosis which in my opinion is an external aponeurosis with the total loss of one of the walls (DULLEMEIJER, 1951, pp. 534/535).

(13) The conical aponeurosis which is attached to two very slight cristae, the muscle fibres of the musculus rectus capitis lateralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) arising from the inside of this aponeurosis, is in my opinion probably an external aponeurosis showing a local reduction or even local loss of the wall (DULLEMEIJER, 1951, p. 536).

(14) The aponeuroses to which the musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached, are in my opinion probably external aponeuroses showing a total loss of one of the walls, as the muscle fibres are attached on the inside of these aponeuroses; this muscle runs to the 1st-6th vertebra (DULLEMEIJER, 1951, p. 536).

(15) The strong and broad aponeurosis to which the 3rd up to and including the 5th branch of the lateral part of the musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. are attached, is no doubt an external aponeurosis showing a total loss of one of the walls, as the muscle fibres are attached to its dorsal surface (DEN BOER, 1953, pp. 458-459; personal communication).

o. The external elongated groove-shaped aponeurosis and the external

V-shaped aponeurosis are not perpendicular to the surface to which they are attached, either directly or by means of a crista or spina, but they make an acute angle with the carrying surface of the skull; this angle may be so small that we may speak of a tangential attachment (plate 19, fig. o). The position of crista and spina in such cases will be discussed later.

Examples: (1) The short aponeurosis for the attachment of the musculus cervico-mandibularis of *Vipera berus* (L.) shows a tangential way of attachment to the most lateral point of the lateral knob on the quadratum (DULLEMEIJER, 1956a, pp. 26-27; on p. 106 a crista is mentioned for cervical muscles; 1956b, pp. 412-413; on p. 492 the same note on a crista).

(2) The strong aponeurosis which on part of its surface bears the attachment of the musculus neuro-mandibularis of *Vipera berus* (L.), shows a tangential position to the ventral ridge of the dentale and continues on the lateral surface of the periost to which it is strongly connected(DULLEMEIJER, 1956a, pp. 27-28; 1956b, pp. 413-414).

(3) The aponeurosis of the musculus cervico-mandibularis of *Crotalus atrox* Baird & Girard and of *Crotalus terrificus* Laur. shows a tangential attachment to the rounded lateral side of the condyle of the lower jaw, and thus not to the quadratum as in *Vipera berus* (L.) (DULLEMEIJER, 1959, p. 908).

(4) The attachment of the (external) aponeurosis of the musculus rectus capitis ventralis major in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. to the lateral side of the processus sphenoideus is partly tangential (DULLEMEIJER, 1959, p. 911).

p. The external aponeurosis shows the shape of an elongated tub; the walls meet at the base along one line (plate 19, fig. p).

q. The external aponeurosis shows the form of a funnel; the walls meet at the base in one point (plate 19, fig. q).

r. The external elongated tub-shaped aponeurosis shows a single aponeurotic plate at the common base of the walls (plate 19, fig. r).

s. The external funnel-shaped aponeurosis is implanted by means of an aponeurotic stalk at its base (plate 19, fig. s).

t. The external tub-shaped aponeurosis shows its walls implanted along a closed round line on the common skeletal surface, so with a space in between (plate 19, fig. t).

u. The external funnel-shaped aponeurosis shows its walls implanted along a closed circular line on the common skeletal surface, so with a space in between (plate 19, fig. u).

v. The external elongated tub-shaped aponeurosis shows in its wall one incision or a number of incisions (plate 19, fig. v).

w. The external elongated tub-shaped aponeurosis lacks the part on one of the narrow ends, this part showing the shape of half a funnel. This reduction could also be considered to be a very deep and a very wide incision at one of the narrow ends (plate 19, fig. w).

x. The external funnel-shaped aponeurosis shows in its wall one incision or a number of incisions (plate 19, fig. x).

Examples: (1) The tendon of the musculus adductor mandibulae internus pterygoideus in *Vipera berus* (L.), which is probably an external one (personal communication) branches off a small one to the connective tissue around the poison-fang (DULLEMEIJER, 1956a, p. 21; 1956b, p. 407); in my opinion this is perhaps due to two deep incisions of this funnel-shaped aponeurosis.

y. The external funnel-shaped aponeurosis lacks half of its form, leaving a half funnel-shaped external tendon. This reduction could also be considered to be a very deep and very wide incision starting from one line on the surface of the funnel (plate 19, fig. y).

z. The external elongated tub-shaped aponeurosis or the external funnel-shaped tendon are not perpendicular to the surface to which they are attached, either directly or by means of a crista or spina, but they make an acute angle with the carrying surface of the skull; this angle may be so small that we may speak of a tangential attachment (plate 19, fig. z). The position of crista and spina in such cases will be discussed later.

(1) (b) The combinations of separate main forms at one muscle-end

As we have discussed above (see pp. 19/20), more than one main form of attachment can occur at each muscle-end. Such a combination of two or three main forms of muscle attachments at one muscle-end can show the following characters:

(b) (α) The combination of a musculous attachment with an internal aponeurosis

Examples: (1) The musculus dorsolateralis in Squaliformes shows an attachment to the skull which is partly musculous, partly takes place by means of internal aponeuroses (MANGER CATS, 1951, pp. 298/299, 300).

(2) The musculus rectus capitis superior in *Phalacrocorax carbo sinensis* (Shaw & Nodder) shows a musculous attachment to an area dorsally of the knob-shaped processus of the basisphenoid and an attachment by means of a tendon, in my opinion perhaps an internal aponeurosis, to the knob-shaped processus; this muscle runs to the 1st-5th vertebra (DULLEMEIJER, 1951, pp. 535/536).

(b) (β) The combination of a musculous attachment with an external aponeurosis

Examples: (1) The musculus coraco-hyoideus in *Squalus acanthias* L. shows an attachment to the copula of the hyoid (not to the hyoid itself) which for the larger part is musculous and which for a smaller part occurs by means of an external aponeurosis; this slightly developed aponeurotic surface is the prolongation of the perichondrium of the copula of the hyoid, to which it is attached (VAN DEN ASSEM, 1952, pp. 658, 661).

(2) The musculus coraco-arcualis I in *Squalus acanthias* L. shows an attachment to the copula of the hyoid which is partly musculous to the caudal border of the copula; for the larger part the muscle fibres attach to a tangential external aponeurosis which becomes more and more an encasing aponeurosis and which is attached to the dorsal surface of the copula of the hyoid where the external shape of the muscle becomes somewhat chisel-like (VAN DEN ASSEM, 1952, pp. 662, 671, 673).

(3) The musculus trapezius anterior in *Sphaeroides oblongus* (Bloch) shows an attachment to the caudal surface of the rostral arm of the temporal process as well as an attachment by means of the dorsal superficial aponeurosis (26) at an angle of about 90° from the caudal surface of this aponeurosis to a narrow and thin area of attachment, which lies on the ventro-lateral pointed edge of the caudo-lateral area of this rostral arm by the muscle fibres of the antero-lateral part of the muscle, like a musculous attachment to a narrow area along the ventral border, extended over the entire projecting process, to about a quarter of its height; on the rest of the caudal surface of this rostral arm of the temporal process at an angle which is smaller than 90° (SARKAR, 1960, p. 63).

(4) The musculus rectus capitis ventralis minor in *Vipera berus* (L.) shows an attachment to the occiput which for the larger part is musculous to the occiput and partly aponeurotic to the processus caudo-lateralis of the basisphenoid (DULLEMEIJER, 1956a, p. 35; 1956b, p. 421; the musculous attachment to the occiput could be on a surface with a slight excavation, see 1956a, p. 106; 1956b, p. 492).

(5) The musculus rectus capitis ventralis major in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. shows an attachment to the processus sphenoideus which is aponeurotic as well as musculous; for a large part it takes place on the dorsal surface of a tendon (in my opinion perhaps an external one), some fibres being musculously attached just dorsal to the tendon (DULLEMEIJER, 1959, p. 911).

(6) The musculus longissimus colli lateralis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. shows a musculous attachment to an excavation lateral to the processus sphenoideus as well as an aponeurotic attachment by means of a short aponeurosis found on a crest, being the border-ridge of this excavation (DULLEMEIJER, 1959, p. 912).

(7) The musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) shows a musculous attachment to an undeep depression, containing an undeep conical depression on the occipital surface of the skull, as well as an aponeurotic attachment by means of a very small and short aponeurosis, which shows the character of a surface aponeurosis (an external aponeurosis with the total loss of one of the walls); this aponeurosis is attached to the very small crista on the processus occipitalis lateralis ossis squamosi, this crista lying on the lateral border of this area of musculous attachment. This muscle runs to the 2nd and the 3rd vertebra (DULLEMEIJER, 1951, pp. 534/535).

(8) The musculus rectus capitis lateralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) shows a musculous attachment of the central part of the muscle bundle to the rough centre of the narrow area of attachment on the most caudal point of the squamosum and an aponeurotic or tendinous attachment to two very slight cristae limiting the first-mentioned area of attachment. This muscle runs to the 2nd-5th vertebra (DULLEMEIJER, 1951, p. 536). Perhaps this combination of a musculous attachment and a conical aponeurotic or tendinous attachment must in my opinion be considered as an external tub-shaped aponeurosis, showing its wall or walls implanted along a closed line on the common skeletal surface, so with a space in between.

(9) The musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) shows a musculous attachment to a triangular area on the ventral surface of the

skull as well as an attachment by means of very strong external aponeuroses attached to two lateral cristae; this muscle runs to the 1st-6th vertebra (DULLEMEIJER, 1951, p. 536).

(b) (γ) The combination of an internal aponeurosis with an external aponeurosis

These aponeuroses can be found in a horizontal and in a vertical mutual position, thus by juxta-position (plate 19, fig. c) or in supra-position (plate 22). Theoretically there is an essential difference between a basal tendo and a stalk.

Examples: (1) The aponeurosis of the antagonist of the musculus dorsolateralis in *Raja batis* L. is for the larger part an external aponeurosis; at its free end it is divided into two branches, one of which probably has the character of an internal aponeurosis (GOTTENBOS, 1956, p. 732).

(b) (δ) The combination of a musculous attachment with an internal aponeurosis and with an external aponeurosis

For the mutual position of the two aponeuroses see above under γ.

Examples: (1) The musculus dorsolateralis in *Raja batis* L. shows an attachment which for a few muscle fibres is a musculous attachment to a concavity on the caudal surface of the regio occipitalis, and for the greater part of the muscle fibres is an attachment to the dorsal surface of the regio occipitalis by means of an internal aponeurosis C and by means of two aponeuroses A and B which combine the characters of an internal with an external aponeurosis (GOTTENBOS, 1956, pp. 726-730). The attachment of the fan-like extension of aponeurosis (A) entirely occupies the rounded ridge of the canalis semicircularis posterior on the dorsal surface of the skull. The fan-like expansion of the aponeurosis (B) is attached to a concavity on the caudal wall of the skull on the lateral sides of the dorsal edge of the foramen occipitale. The attachment of the two longitudinal horizontal layers of aponeurosis (C), fused to a certain degree and attached to the skull at the same place, is connected to the horizontal part of the transition of the round ridge above the canalis semicircularis posterior into the rod γ (read α) (GOTTENBOS, 1956, pp. 726-730, 734).

(2) The antagonist of the musculus dorsolateralis in *Raja batis* L. is attached to the caudal surface of the regio occipitalis musculously and to the ventral surface of this regio occipitalis by means of an aponeurosis. This aponeurosis is for the larger part an external aponeurosis; the free end of this aponeurosis, however, is divided into a branch directed ventralwards and a branch in a dorso-lateral direction; this latter branch probably has the character of an internal aponeurosis (GOTTENBOS, 1956, pp. 730-734).

(3) The musculus supracranialis in *Sphaeroides oblongus* (Bloch) shows at the anterior end the following ways of attachment in the five portions of the muscle: in the first portion an attachment occurs for the left and right big cylindrical bundle of the muscle fibres to the common aponeurosis of the left and the right side of aponeurosis (34), showing a short and narrow area of attachment to the caudal rim of the posterior projection of the occipital spine; in the second portion, which is thinner and broader than the portion 1, an attachment occurs to the thin aponeurosis (35) connected to the small spine on the dorsal surface of the parietale and latero-dorsal to the base of the occipital spine, showing a short, round and slightly ridged area of attachment; in the third portion, which is broader than portions 1 and 2, occurs an attachment by means of the aponeurosis (36) to the posterior part of the aponeurosis (19) of the musculus dilatator operculi pars medialis and also to supracleithrum and postcleithrum; the fourth portion, which is a short bundle of muscle

fibres covered by portion 1, has an aponeurotic attachment by means of aponeurosis (37) to a narrow area situated on the ventral ridge of the occipital spine, as well as a musculous attachment on the lateral surface of the occipital spine; in the fifth portion, which is bigger than portion 4, there is a musculous attachment of the most medial muscle fibres to the triangular surface on the cerebral skull ventral to the occipital spine and an anterior attachment of the muscle fibres lateral to these medial fibres to the rounded posterior surface of the parietale; one also finds an aponeurotic attachment by means of aponeurosis (39) of a few dorsal muscle fibres to the paired pointed spinous structure present at the junction of the base of the postfrontale and the parietale; furthermore, there is an aponeurotic attachment of some muscle bundles running over the parietal region of the skull to the aponeurosis (19) of the musculus dilatator operculi pars medialis (SARKAR, 1960, pp. 71-73). Though the nature of the aponeuroses is not indicated, it is in my opinion probable that there are internal as well as external aponeuroses among them.

(4) The musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. shows an attachment to the caudal wall of the skull, which is partly musculous (the direct attachment of the 1st and 2nd branch of the lateral part of the muscle), partly aponeurotic as occurs with the 3rd, 4th and 5th branch of the lateral part of the muscle in their attachment to the dorsal surface of a strong and broad aponeurosis, attached to the caudal wall of the skull, and partly tendinous as occurs with the three branches of the medial part of this muscle; in my opinion this tendon is perhaps an internal one (DEN BOER, 1953, pp. 458, 459; personal communication).

(1) (c) The topographical relations of the different kinds of muscle attachments

It seems useful to incorporate here a review of the various categories with regard to the topographical relations of the different kinds of muscle attachments, in case that at such a muscle-end under investigation more than one main form of attachment occurs. The following categories may be distinguished:

a) On one of the muscle-ends there is an elongated plate-like internal aponeurosis and/or an elongated groove-shaped external aponeurosis and a musculous attachment, whereas the area of the latter attachment is contiguous with the base of the internal or external aponeurosis of the above-mentioned shape along the entire length of its longitudinal axis at both sides or at one side. This condition is taken as a standard form on pp. 18, 18 and 19 and in the plates 1-18.

Examples: (1) Of the musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder), the very small and short aponeurosis, which shows the character of a surface aponeurosis (an external aponeurosis with total loss of one of the walls), attached to the very small crista on the processus occipitalis lateralis ossis squamosi, is at one end contiguous with the area of musculous attachment to the occipital surface (DULLEMEIJER, 1951, pp. 534/535).

(2) Of the musculus rectus capitis superior in *Phalacrocorax carbo sinensis* (Shaw & Nodder), the knob-shaped processus of the basisphenoid to which a tendon is attached, is contiguous with the area of musculous attachment (DULLEMEIJER, 1951, pp. 535/536).

(3) Of the musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw &

Nodder), the lateral cristae to which very strong external aponeuroses are attached, are contiguous with the area of musculous attachment (DULLEMEIJER, 1951, p. 536).

(4) Of the lateral part of the musculus splenius capitis in *Anas platyrhyncha platyrhyncha* (L.) the crista occipitalis, to the ventral half of which an aponeurosis (probably a superficial one) is attached, is contiguous with an area of musculous attachment of a smaller part of the muscle fibres of this part of the muscle (DAVIDS, 1952, p. 536).

β) On one of the muscle-ends a tendon-like internal and/or a V-shaped external aponeurosis and a musculous attachment occurs, whereas the area of the latter attachment is contiguous with the base of these tendons, closely surrounding their base. This condition is taken as a standard form on pp. 18, 19 and 19/20, and in the plates 1-18.

Examples: (1) The musculus rectus capitis ventralis in *Phasianus colchicus* L. and in *Perdix perdix* L. shows an attachment to the knob of the basisphenoid. The median part shows this attachment in an entirely musculous way, one bundle in front of the other. In *Phasianus* the attachment of the muscle fibres of the median part thus occurs at quite different angles: nearly 90° to practically 0° (so here the attachment is about tangential). In *Perdix* the muscle fibres are nearly all attached to the knob of the basisphenoid at about the same angle. The lateral part of the muscle is attached by means of a tendon, which in *Phasianus* is attached to the knob of the basisphenoid quite laterally and rather far rostrally (DEN BOER, 1953, pp. 463-467).

γ) On the skull-end of a segmented muscle with a number of parallel transversely situated myosepta, acting as internal aponeuroses, a number of the foremost aponeuroses are found in the skull-end, while these aponeuroses show a curved course and give rise to an aponeurotic attachment to the skull.

δ) On one of the muscle-ends there occurs an elongated plate-like internal aponeurosis or (and) an elongated groove-shaped external aponeurosis and a musculous attachment, while the area of this attachment lies at one end or at both ends of the plate-like base of these aponeuroses to which it/they is/are connected.

Examples: (1) Of the musculus longissimus dorsi in *Rana esculenta* L. the aponeurosis, attached to the synchondrosis prootico-exoccipitalis, is at one end contiguous with the area of musculous attachment to the frontoparietale (we assume that the aponeurosis is a pure one and not partly musculous) (COOL, 1952, pp. 640/641).

(2) Of the musculus intertransversarius capitis superior in *Rana esculenta* L. the aponeurosis, attached to the crista of the exoccipitale, is at one end contiguous with the area of musculous attachment to the synchondrosis prootico-exoccipitalis (COOL, 1952, p. 641).

(3) Of the musculus levator scapulae superior in *Rana esculenta* L. the aponeurosis lying laterally and latero-ventrally of the operculum, is at one end contiguous with the area of musculous attachment lying medio-ventrally and medially of the operculum (COOL, 1952, p. 642).

(4) Of the musculus levator scapulae inferior in *Rana esculenta* L. the aponeurosis,

attached to the cartilage on the lateral side of the transverse leg of the parasphenoid, is at one end contiguous with the area of musculous attachment to parasphenoid and exoccipitale (Cool, 1952, pp. 642/643).

(5) Of the musculus rhomboideus anterior in *Rana esculenta* L. one or both aponeuroses, attached to cristae on the frontoparietale, is/are at one end contiguous with the area of musculous attachment to the frontoparietale (Cool, 1952, p. 643).

(6) Of the musculus complexus in *Anas platyrhyncha platyrhyncha* (L.) the aponeurosis attached to the crista occipitalis on the caudal surface of the occipital plane, is at its dorsal end contiguous with the small area of musculous attachment to this occipital plane (Davids, 1952, p. 536).

ε) On one of the muscle-ends there occurs a tendon-like internal aponeurosis or (and) a V-shaped external aponeurosis and a musculous attachment, while this area of attachment lies at one side of the base of the tendon to which it is connected; in some cases we find an area of musculous attachment to two opposite sides of the base of such a tendon.

Examples: (1) Of the musculus rectus capitis ventralis in *Anas platyrhyncha platyrhyncha* (L.), the narrow and short area of aponeurotic attachment is contiguous with the large area of musculous attachment; it adjoins a small part of the long margin of the larger area of musculous attachment (Davids, 1952, p. 537).

ζ) On one of the muscle-ends there occurs a combination of two or three main forms of muscle attachment, whereas in some cases their places of attachment are separated by a bare, unoccupied strip on the surface of the skull.

Examples: (1) Of the musculus levator scapulae superior in *Rana esculenta* L., the area of musculous attachment to the operculum with regard to those on the cartilage which are ventro-lateral and medio-ventral of it (Cool, 1952, p. 642).

(2) Of the musculus rhomboideus anterior in *Rana esculenta* L., the most dorsal aponeurotic attachment with regard to the musculous attachment and to the more ventral aponeurotic attachment (Cool, 1952, p. 643).

(3) Of the musculus splenius capitis in *Anas platyrhyncha platyrhyncha* (L.), the area of aponeurotic and musculous attachment of the lateral part of the muscle fibres with regard to the area of musculous attachment of the medial portion of these muscle fibres (Davids, 1952, p. 536).

η) On one of the muscle ends there is an elongated plate-like internal aponeurosis and an elongated external aponeurosis, whereas these two are not only contiguous, but are fused together to form a combined structure, showing a plate-shaped aponeurosis which for a part of its surface is an internal aponeurosis and for another part of its surface is an external aponeurosis (plate 20).

Examples: (1) The very complex branched or ramified aponeurosis (4) of the musculus adductor mandibulae externus in *Phasianus colchicus* L. contains the ossified element (4a), which is a combination of an internal and partly of a surface aponeurosis (BURGGRAAF, 1954, pp. 299, 300, 303; BURGGRAAF & FUCHS, 1955, p. 98).

The topographical relations — not of two or three main forms of attachment, but of two or more sub-types of one and the same main form of muscle attachment in one muscle-end —, form another interesting question. A review of the various categories in this line does not seem necessary. We will mention a number of groups only:

α) the topographical relation of different sub-types of an internal aponeurosis, combined in juxtaposition in the sense of a local blending of an elongated plate-shaped internal aponeurosis and a marginal cylindrical or cone-shaped internal tendon; see text on p. 23 under c; plate 19, fig. c).

Examples: (1) Of the musculus adductor mandibulae externus in *Phasianus colchicus* L. aponeurosis (6), which is an internal one (personal communication), shows a thickened medial border which has the character of a tendon especially at the attachment, whereas the lateral part of this aponeurosis is rather thin (BURGGRAAF, 1954, pp. 300, 303; BURGGRAAF & FUCHS, 1955, p. 98).

β) the topographical relation of different sub-types of an internal aponeurosis, combined in supraposition in the sense of a basic tendon which spreads as a conical tendon and extends towards the centre of the muscle as internal aponeurosis.

Examples: (1) In the musculus adductor mandibulae externus superficialis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) this occurs with the caudal aponeurosis (A) and with the rostral aponeurosis (C) (DULLEMEIJER, 1951, pp. 249-253; personal communication; DULLEMEIJER, 1958, p. 76).

(2) In the musculus adductor mandibulae externus in *Phasianus colchicus* L. this occurs with the aponeurosis (3), which is an internal one (personal communication), which at its thickened base has the character of a tendon and which at its free end has the character of an aponeurosis (BURGGRAAF, 1954, pp. 297, 303; BURGGRAAF & FUCHS, 1955, p. 98; DULLEMEIJER, 1958, p. 76).

(3) In the musculus adductor mandibulae externus in *Ardea cinerea* (L.) this occurs with the fan-shaped internal aponeurosis (1), which begins as a narrow flat tendon but soon spreads into a fan-like aponeurosis (BAS, 1954, p. 682; DULLEMEIJER, 1958, p. 76).

(4) In the musculus adductor mandibulae externus in *Ardea cinerea* (L.) this occurs with the internal aponeurosis (7), which is attached to the spina (7), but spreads like a fan (BAS, 1954, p. 685).

The topographical relations — neither of two or three main forms of attachment, nor of two or more sub-types of one and the same main form of muscle attachment, but of one and the same sub-type within one and the same main form of attachment, showing different details in the way of attachment, however — form a third group of interesting questions.

Examples: (1) Of the musculus pterygoideus ventralis medialis in *Anas platyrhyncha platyrhyncha* (L.) the aponeurosis is attached partly to a crista, partly to the skeletal surface itself; in this case there occurs a very sharp angle between the aponeurosis with its crista and the skeletal surface of attachment; then the periost in front of the crista shows an aponeurotic structure (DAVIDS, 1952, p. 531).

(iii) (2) Forms of the projections, deepenings and undulations of the surface of the skull

(2) (a) Introduction

Above we have described three main forms of the surface of the skull established by us as a standard: the smooth, flat surface, the crista and the spina.

We find many deviations from these standard forms in many conditions occurring in nature.

For a correct understanding of these conditions, the name and definition to be assigned to them, it seems inevitable to insert a general survey about all types of projections on and deepenings in the surface of the skull (so also without the restriction to the forms of the surface of the skull which we know as places of attachment of muscles).

(2) (b) General survey about all types of projections and deepenings on the surface of the skull

We will define these types merely according to their spatial form, so without further limiting the notion on the ground of a function, as we already did above in the case of the crista and the spina. There is no limitation to the surface elements known as places of attachment of muscles. According to the spatial form we may distinguish three groups:

(b) (α) Protuberant elements

When first inserting a general survey of all types of places that are protuberant in relation to the carrying surface, and in which the carrying surface is a plane of the surface of the object, we can distinguish six types (plate 21). They are:

The protuberant element or the protruding spot is characterized by two basal dimensions, running across the said carrying surface, one of which is a long, straight line, the other being considerably shorter, as is generally also the case with the height (plate 21, fig. A). This main type A can be distinguished into five sub-types. They are:

a. The protuberant element approximates the stereometric high and thin parallelepipedum with rectangular planes, one of the small planes being embedded in the carrying surface; the breadth of this rectangular plane and of the rectangular free edge is slight in relation to their length; the length and the height of the front and back surface, which is either a rectangle or a square (quadrate), are large in relation to the breadth of the small basal plane. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric body in the described position can be called a plattum (E. plate; F. plat; G. Platte) (plate 21, fig. Aa).

b. The protuberant element approximates the stereometric low and thick parallelepipedum with rectangular planes, one of the long planes being embedded in the carrying surface; the thickness on the basic side is considerable in relation to the height of the body; the length and the height of the front and back surface, which is either a rectangle or a square (quadrate), are of the same type of size as the dimensions of the basal plane and the opposite free plane. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric body in the described position can be called a trabecula (E. rafter; F. poutre; G. Balken) (plate 21, fig. Ab).

c. The protuberant element approximates the stereometric triangular prisma with rectangular side-planes, one of which is embedded in the carrying surface; the two triangular end-planes being perpendicular to the carrying surface. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric body in the described position can be called a crista (E. crest; F. crête; G. Kamm). In such a crista the thickness on the plane embedded in the carrying surface is distinctly greater than on the free edge, the crista being acutely triangular in cross section; the thickness at the base of this triangle is as a rule about as great as the height; the free edge is distinctly sharp, and on either side of the crista the carrying surface of the skull is about on the same level (see MANGER CATS, 1951, p. 193; DULLEMEIJER, 1951, p. 247; DAVIDS, 1952, p. 81) (plate 21, fig. Ac). (DULLEMEIJER, 1956a, pp. 37, 38, 39, 40, 107; 1956b, pp. 423, 424, 425, 426, 493 uses the term crista, crista-like ridge, *etc.* in a functional sense and in a broader morphological sense, *e.g.* also in the sense of a freely protruding margin of a plate-shaped extension; there is a gradual transition between a crista on the thick, rounded margin of a skeletal element and the sharp edge of a plate-shaped extension.)

d. The protuberant element approximates the stereometric quadrangular prisma with rectangular side-planes, one of which is embedded in the carrying surface, and with two end-planes, showing the contour of a trapezium and being perpendicular to the carrying surface. In such a protruding element the thickness on the plane embedded in the carrying surface is as a rule about as great as the height and is considerable in relation to the breadth of the narrow flat free upper surface. In descriptive anatomy a protuberant element, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a trabecula cum forma prismae quadrangularis (E. ledge, better rafter with the form of a quadrangular prism; F. poutre à forme prismatique quadrangulaire; G. Balken in Form eines viereckigen Prismas) (plate 21, fig. Ad). MANGER CATS (1951, p. 194) calls a ledge a transitional form between a crista and a ridge, thus an elongated projection with a trapeziform or a triangular cross-section.

e. The protuberant element approximates the stereometric body, the surface of which is partly cylindriform and partly shows at least one rectangular side-plane which is embedded in the carrying surface; it shows two end-planes displaying the contour either of a half-circle (segment of a circle) or of a triangle with rounded margins of the free upper surface which is flat or also rounded; these end-planes are perpendicular to the carrying surface. In such a protuberant element the thickness on the plane embedded in the carrying surface is as a rule about as great as the height. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric body in the described position can be called a costa s.l. (E. rib in the widest sense; F. côte dans le sens ample; G. Rippe im weitesten Sinne). Two forms can be distinguished in this, dependent of the condition on the free upper surface and of the contour of the transverse section:

α) We want to refer to a margo rotundatus (E. rounded ridge; F. bord arrondi; G. abgerundete Leiste), when the transverse section is a half circle or a segment of a circle (MANGER CATS, 1951, p. 194 (plate 21, fig. Aeα).

β) We want to refer to a costa (E. rib; F. côte; G. Rippe) when the transverse section is a triangle with rounded margins of the free upper surface which is flat or also rounded; when it is flat, the free upper surface is narrow and obtuse (DULLEMEIJER, 1951, pp. 247/248; DAVIDS, 1952, p. 81) (plate 21, fig. Aeβ).

It stands to reason that in nature there are all sorts of transitions among the forms we distinguished as sub-types. Also, the free edge of a crista is never without some breadth, which is obvious when we remember the fact that an aponeurosis may be attached to it. The free upper edge of a crista, therefore, is not smooth, but rough. Thus there are also all sorts of imaginable transitions between a plate and a rafter, among a crest, a ledge, a rounded ridge and a costa.

The term "band" is used by MANGER CATS (1951, p. 194) as a neutral name for formations like a rounded ridge, a ledge and a crista and also for a protruding margin. MANGER CATS (1951, p. 194) calls the cartilaginous covering of the horizontal semicircular canal in Squaliformes a band.

B) The protuberant element or the protruding spot is characterized by two basal dimensions, embedded in and running across the said carrying surface only over short distances, and which are considerably shorter than the axis of the protuberant element which is perpendicular to the carrying surface. In these cases we speak of a processus s.l. (E. process; F. processus; G. Fortsatz) (plate 21, fig. B). This main type B can be distinguished into four sub-types. They are:

a. The protuberant element approximates the stereometric prisma or cylinder (E. prism or cylinder; F. prisme or cylindre; G. Prisma or Zylinder), one of the two parallel end-planes being embedded in the carrying surface; the transverse section and the free upper surface showing the shape of a triangle, of a quadrangle, of a polygon or of a circle; the height can be greater than, equal to, and smaller than a dimension of the transverse section. In other words, the prism or the cylinder can be high or low. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric body in the described position can be called a high or low prismoidal process or a high or low cylindriform process (plate 21, fig. Baα, Baβ and Baγ).

b. The protuberant element approximates the stereometric pyramis (E. pyramid; F. pyramide; G. Pyramide) or the stereometric conus (E. cone; F. cône; G. Kegel), the polygonal or circular basal plane being embedded in the carrying surface; the diameter at the base is usually small in comparison to the height and is distinctly greater than at the free apex or the free end. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric bodies in the described positions can be called a pyramidal process or a conical process or a spina (E. spine; F. épine; G. Dornfortsatz); the free apex or free end tapers off towards the end like the tip of a thorn or prickle (DULLEMEIJER, 1951, p. 247; DAVIDS, 1952, p. 81) (plate 21, fig. Bbα, Bbβ and Bbγ).

c. The protuberant element approximates the stereometric truncated pyramid or the truncated cone, having the vertex cut off by a transverse plane section, the polygonal or circular basal plane being embedded in the carrying surface. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric bodies in the described positions can be called a truncated pyramidal process or a truncated conical process or a truncated spina. The free truncated apex is flat or rounded off and never distinctly sharp. In the case it is rounded off, the truncated cone may be called a tuber (E. tuber; F. tubercule; G. Tuberkel) (DULLEMEIJER, 1951, p. 248; DAVIDS, 1952, p. 81) (plate 21, fig. Bcα and Bcβ).

d. The protuberant element approximates the stereometric segment of a sphere or the half sphere, the circular basal plane being embedded in the carrying surface. In descriptive anatomy a protuberant element showing the principal characters of the above-mentioned stereometric bodies in the described position can be called a semi-nodus (E. half-knob; F. semi-protubérance; G. Halbknollen) (DULLEMEIJER, 1951, p. 248: bulla; DAVIDS, 1952, p. 81: bulle) (plate 21, fig. Bd).

It goes without saying that, here too, there are in nature all sorts of transitions among the shapes described as sub-types, *e.g.* between a tuber and a knob. When we remember that the free end of a spine can hold the place of attachment of an aponeurosis, it is understandable that this free end ends in a very small plane with a rough surface, which gives the transition between a spina and a truncated spina in the form of a tuber.

C) The protuberant element is characterized by two basal dimensions, embedded in and running across the said carrying surface which lies at the place where two planes of the carrying surface meet under an angle, thus one of the basal dimensions being a long, straight line, the other very narrow; the height or breadth of the protuberant element is more or less considerable. In descriptive anatomy a protuberant element, showing the principal characters of the above-mentioned stereometric body in the described position can be called a margo eminens cum acie acuto (E. protruding margin with a sharp edge; F. bord saillant à coup aigu; G. vorspringender Rand mit scharfer schneidender Linie) (MANGER CATS, 1951, pp. 193/194) (plate 21, fig. C), or a margo eminens cum acie obtuso (E. protruding margin with an obtuse edge; F. bord saillant à coup obtus; G. vorspringender Rand mit stumpfer schneidender Linie). In skulls such a projecting, overlapping edge is formed by the continuance of the surface of the skull at that place, where two planes of this surface meet under an angle, giving rise to a projecting ridge. One might call a special case of this situation a rather thin, rather long, narrow skeletal element, which is broadened; the broadening serving for the attachment of a highly developed muscle (according to SARKAR, 1960, p. 99, the breadth of the maxilla can be attributed to the area for muscle attachments).

D) The protuberant element approximates the stereometric high and thin parallelepipedum, one of the small planes being embedded in the carrying surface formed by the bottom and side-walls of a hollow spherical body, the upper segment on the side of the free surface of which is lacking. In descriptive anatomy a protuberant element, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a septum (E. septum; F. cloison; G. Zwischenwand) (plate 21, fig. D).

E) The protuberant element approximates the stereometric high and thin parallelepipedum, forming the plane of partition between two hollow semi-spherical bodies, the upper segment on the side of the free surface is lacking; this plane of partition primarily will reach the surface of the truncated semi-spherical bodies. In descriptive anatomy a protuberant element, showing the principal characters of the above-mentioned stereometric body, can be called a septum as well (E. septum; F. cloison; G. Zwischenwand) (plate 21, fig. E).

F) The protuberant element approximates none of the stereometric bodies mentioned above and deviates from the protuberances mentioned under the preceding headings. These elements are embedded either on a free upper surface of the carrying surface or on the bottom or side-walls of a hollow spherical body. In descriptive anatomy such a protuberant element is called an antler on the surface of the skull, a concha in the nose-cavity, *etc.*

All above-mentioned six main types of protuberant elements show variations. In a few cases the variations could be clearly distinguished, even by a distinct name. A number of these variations were distinguished as sub-types. Thus the first main type was broken up into five sub-types. The fifth sub-type of the first main type showed two variations. The second main type was broken into four sub-types. The first three sub-types of the second main type showed two variations each. The third main type showed two variations. In total we thus came to eighteen sorts of protuberances which we could define.

(b) (β) Sinkings and hollowings

When, in the second place, we now insert a general survey of all types of sinkings and hollowings in the surface of a body sunk inwards in regard to the carrying surface, we find the following. Here again we do not make any restriction to the forms of the skull, which we know as places of attachment of muscles and here too we will define these types merely according to their spatial form, so without further limiting the notion on the ground of a function, as we already did above. There are three types:

G) The sinking approximates the longitudinal segment of a stereometric spheroid or of a stereometric cylinder, both ends of the longitudinal axis being rounded off. The longitudinal axis is a long, straight line running parallel to and in or under the surface of the carrying surface; this longitudinal axis is as a rule considerably longer than the two other dimensions (the breadth and the depth). This main type can be distinguished into four sub-types. They are the following:

a. The sinking approximates the longitudinal segment of a stereometric spheroid, the breadth in the middle of the longitudinal axis being fairly wide as compared with the breadth at spots more remote from this middle and nearer to the ends of the longitudinal axis; the breadth in the middle of the longitudinal axis is not inconsiderable as compared with the length; the depth is fairly considerable. In descriptive anatomy a sinking, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a fossa (E. groove; F. fosse; G. Grube) (DULLEMEIJER, 1951, p. 248; DAVIDS, 1952, p. 81) (plate 22, fig. Ga).

b. The sinking approximates the longitudinal segment of a stereometric spheroid, the breadth in the middle of the longitudinal axis being fairly wide as compared with the breadth at spots more remote from this middle and nearer to the ends of the longitudinal axis; the breadth in this middle is not inconsiderable as compared with the length; the depth, however, is slight. In descriptive anatomy a sinking, showing the principal characters of the above-mentioned stereometric body in the described position, can be called an impressio (E. impression; F. empreinte; G. Eindruck) (plate 22, fig. Gb).

c. The sinking approximates the longitudinal segment of a stereometric cylinder, the breadth over the bulk of its longitudinal length being practically just as broad; this breadth is slight in comparison with the length; the depth is also slight. In descriptive anatomy a sinking, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a sulcus (E. groove or furrow; F. cannelure; G. Rinne) (plate 22, fig. Gc).

d. The sinking approximates the longitudinal segment of a stereometric spheroid, the breadth over the bulk of its longitudinal length being practically just as broad, but very slight in comparison with the length; the depth, however, is very great. In descriptive anatomy a sinking, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a fissura (E. fissure or cleft; F. fissure; G. Spalte) (plate 22, fig. Gd).

H) The sinking approximates the segment of a stereometric spheroid, the flat plane of the segment lying in the surface of the carrying surface; the perpendicular to this last-mentioned surface and to the flat plane of the segment is equal, or shorter than the two dimensions of about the same length running parallel to the surface of the carrying surface. The access opening to this hollowing is not narrower than the measurement shown by the cross-section of this sinking at any distance under the surface. In descriptive anatomy a sinking, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a pelvis (E. bowl or ball-shaped pit; F. cuvette; G. Becken). This bowl is as a rule an extremely small spot sunk into the carrying surface (plate 22, fig. H).

I) The sinking or hollowing shows all characteristics of the sinking discussed just now, but the diameter of the skeletal access opening is reduced in regard to the cross-section under the carrying surface. In descriptive anatomy such a sinking can be called a sinus (E. sinus; F. sinus; G. Sinus) (plate 22, fig. I).

All above-mentioned three main types of sinkings or hollowings show variations. In one case the variations could be clearly distinguished, even by a distinct name. A number of these variations were distinguished as sub-types. Of all above-mentioned three main types the first was broken up into four sub-types, so that in total we came to six kinds of sinkings that could be defined.

We think it unnecessary to point out in detail that in nature there occur all sorts of transitions among the types and sub-types that we have discussed.

(b) (γ) Very low projections, very shallow deepenings and very slight undulations

In the third place we still have to insert here a general survey of all types of elements of the surface of a body, consisting of very low projections, very shallow deepenings and very slight undulations of the surface of the body, which deviate from the general surface of the carrying surface to such a small extent, that we can neither markedly allocate them to the protuberances, nor markedly to the sinkings. These cases can be subdivided into four types (plate 22):

J) The extremely low or shallow element of the surface of the body approximates the stereometric parallelepipedum or cylinder, the longest axis running parallel to the surface of the carrying surface, the breadth and the depth being extremely slight. In descriptive anatomy such an element or spot, showing the principal characters of the above-mentioned stereometric body in the described position, can be called a linea (E. line; F. ligne; G. Linie) (VAN VENDELOO, 1953, pp. 116, 276) (plate 22, fig. J).

K) The extremely low or shallow element of the surface of the body approximates the stereometric parallelepipedum, the longest axis running parallel to the surface of the carrying surface, the breadth being somewhat extensive, but distinctly smaller than the length; the depth being extremely slight. In descriptive anatomy such an element or spot, showing the principal characters of the above-mentioned stereometric body in the described position, can be called an area (E. field; F. champ; G. Feld) (VAN VENDELOO, 1953, p. 276) (plate 22, fig. K).

L) The extremely low or shallow element of the surface of the body approximates the stereometric cylinder, the longitudinal axis being perpendicular to the surface of the carrying surface, the other two axes running parallel to the surface of the carrying surface; these last-mentioned axes are about equal in length and can be short or longer;

the height or depth is extremely slight. In descriptive anatomy such a spot, showing the principal characters of the above-mentioned stereometric body in the described position, can be called an elevatio or excavatio circularis et tenuis (E. circular shallow or low spot; F. enfoncure circulaire et peu profonde; G. kreisförmige und untiefe Beule).

M) The extremely low or shallow element of the surface of the body approximates the closed ring without a material centre. In descriptive anatomy this very low or very shallow element of the surface of the skull is the non-protruding or hardly protruding and the non-sunken or hardly sunken edge around and along the skeletal outlet of a perforation or a canal, which may end perpendicularly or obliquely on the carrying surface. In such cases we speak of an anulus superficialis (E. superficial ring; F. anneau superficiel; G. oberflächlicher Ring) (plate 22, fig. M).

It will be self-evident that among the last-mentioned main types of very low projections, very shallow deepenings and very slight undulations there occur all sorts of transitions with the elements lying on the surface level of the skull, and also among these four main types.

We want to point out once again that — in the general survey of the elements or spots on the surface of the skull — the above-mentioned and defined elements and spots with a deviating shape have only been mentioned and defined according to their spatial form. A limitation or further precise statement on the ground of a function was not brought into question.

(2) (c) Survey of the types of projections and deepenings on the surface of the skull playing a part in the attachment of muscles

(c) (α) No function in the attachment of muscles

We will now revert to our explanation which we interrupted at the beginning of paragraph (b) (p. 35).

Not all of the elements or spots on the surface of the skull summarized in the above general survey play a part in the attachment of muscles. As far as I know, such is not the case with six of the eighteen sorts of protuberances which we could define, *viz.* the rafter (trabecula) (Ab), the prism (prisma) (Ba), the cylinder (cylinder) (Ba), the two kinds of septa (septa) (D, E) and the deviating protuberances (F). As far as I know neither is this so with one of the six sorts of sinkings which we could define, *viz.* the fissure or cleft (fissura) (Gd). Of all above-mentioned four main types of elements or spots lying on the level of the carrying surface, consisting of very low projections, very shallow deepenings and very slight undulations, no examples are known of no function in the attachment of muscles.

(c) (β) Elements of the surface for the attachment of muscles

The remaining elements or spots on the surface of the skull summarized in the above general survey play a part in the attachment of muscles.

The shape of these elements or spots on the surface of the skull is of course not a purely stereometric form. Thus *e.g.* the free edge of a crista is not a sharp line, but in relation to its function as an area of attachment of muscle fibres it has a certain breadth. According to VAN VENDELOO (1953, p. 276), there must be an area composed of many very minute granulations on the surface of the bone, to each of which a tendinous fibre is connected. According to this author this narrow area of attachment may be found as a line on the flat surface of the bone, but also as a line on the top of a crista or in a fossa.

Setting aside this aberration of the stereometric form, we may say that the remaining elements or spots on the surface of the skull, which do play a part in the attachment of muscles, are the following main types or sub-types:

(β) (a) Protuberances on the surface

As to these protuberances on the surface twelve sorts which we could define play a part in the attachment of muscles, *viz.* the plate (plattum) (Aa), the crest (crista) (Ac), the rafter with the form of a quadrangular prism or the ledge (trabecula cum forma prismae quadrangularis) (Ad), the rounded ridge (margo rotundatus) (Ae), the rib (costa) (Ae), the pyramid (pyramis) or spine (spina) (Bb), the cone (conus) or spine (spina) (Bb), the truncated pyramid (Bc), the truncated cone (Bc), the half-knob (semi-nodus) (Bd), the protruding margin with a sharp edge (C) and the protruding margin with an obtuse edge (margo eminens cum acie acuto et obtuso) (C).

Examples of a plattum or plate (Aa): no examples are given in the literature mentioned.

Examples of a crista or crest (Ac):

(1) The anterior, downward-sloping rim of crista (6) is occupied by the area of attachment of the musculus sternohyoideus in *Sphaeroides oblongus* (Bloch) on the rostral curved end of the ceratohyale (next to the hypohyale) and on a very small place on the posterior rim of this crista (6) on the hypohyale (SARKAR, 1960, p. 61).

(2) The ventro-lateral pointed edge on the caudo-lateral area of the rostral arm of the temporal process, on which the narrow and thin area of aponeurotic attachment for aponeurosis (26) lies, is in my opinion perhaps a crista (SARKAR, 1960, p. 63).

(3) A little crista on the caudo-dorsal point of the quadratum bears the surface of attachment of the tendon of the musculus retractor quadrati of *Vipera berus* (L.); this muscle runs into a caudo-ventral direction where it is aponeurotically attached to the skin in the cervical region (DULLEMEIJER, 1956a, p. 25; on p. 106 the attachment of the tendon to a spina is mentioned; 1956b, p. 411; on p. 492 the same note on the spina).

(4) To the rostral lobe of the crista on the supraoccipitale the external aponeurosis of the musculus spinalis capitis in *Vipera berus* (L.) is attached; this muscle runs to the cervical region (DULLEMEIJER, 1956a, pp. 32-33, 106; 1956b, pp. 418-419, 492).

(5) To the rostral and partly to the caudal lobe of the crista on the supraoccipitale and the exoccipitalia, the external aponeurosis of the musculus longissimus capitis in *Vipera berus* (L.) is attached; this muscle runs to the cauda (DULLEMEIJER, 1956a, pp. 33, 106; 1956b, pp. 419, 492).

(6) To the caudo-lateral part of the crista on the exoccipitalia, the external aponeurosis of the musculus ilio-costalis occipitalis in *Vipera berus* (L.) is attached; this muscle runs to the cauda (DULLEMEIJER, 1956a, pp. 33, 106; 1956b, pp. 419, 492).

(7) To the processus caudo-lateralis of the transverse crista of the basisphenoid, the external aponeurosis of the musculus longissimus colli lateralis in *Vipera berus* (L.) is attached; this muscle runs caudalwards to the body (DULLEMEIJER, 1956a, p. 34; p. 106 mentions that the small crista has the appearance of a spina; 1956b, p. 420; on p. 492 the same note on the spina).

(8) To the crista occipitalis with its enlargement from the medial plane to the medial point of the semicircular wall, the external aponeurosis of the second part of the musculus spinalis capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. is attached; this muscle runs to the cervical region (DULLEMEIJER, 1959, p. 910).

(9) To the crista occipitalis, from lateral to half-way medial-lateral, the aponeurosis of the musculus longissimus capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. is attached; this muscle runs to vertebrae (DULLEMEIJER, 1959, p. 911).

(10) The border-ridge of the excavation in which the musculous attachment of the musculus longissimus colli lateralis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. takes place, gets the character of a crista; on this crest a short aponeurosis is found from the area of musculous attachment in the excavation to a place caudal of the fenestra ovalis; the muscle runs to the hypapophysei of the 3rd-8th vertebra (DULLEMEIJER, 1959, p. 912).

(11) To the crista occipitalis, from the articulation-knob with the os accessorium as far as the point, where the crista occipitalis bends caudalwards, the aponeurosis of the musculus complexus in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached; this muscle runs to the 3rd, 4th and 6th vertebra (DULLEMEIJER, 1951, p. 533).

(12) To the very small crista on the processus occipitalis lateralis ossis squamosi, the very small and short aponeurosis, which shows the character of a surface aponeurosis (an external aponeurosis with total loss of one of the walls) of the musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached; most of the muscle fibres are attached to an area of musculous attachment on the occipital surface; this muscle runs to the 2nd and the 3rd vertebra (DULLEMEIJER, 1951, pp. 534/535).

(13) On the ventral surface of the skull to a lateral crista or a sharp edge, becoming broader and higher caudalwards, becoming narrower again for some millimetres, external aponeuroses and especially upon the broadened parts of the cristae very strong aponeuroses of the musculus rectus capitis ventralis of *Phalacrocorax carbo sinensis* (Shaw & Nodder) are attached; most of the muscle fibres are attached to an area of musculous attachment on the ventral surface of the skull; this muscle runs to the 1st-6th vertebra (DULLEMEIJER, 1951, p. 536).

(14) On the caudal surface of the occipital plane to a crista the aponeurosis of the musculus biventer cervicis in *Anas platyrhyncha platyrhyncha* (L.) is attached; this muscle runs to the base of the neck (DAVIDS, 1952, pp. 534-536).

(15) On the occipital plane to the larger part of the dorsal half of the crista occipitalis, part of the musculus complexus in *Anas platyrhyncha platyrhyncha* (L.) is attached in an aponeurotic way; the entire muscle runs to the lateral surfaces of the 3rd, 4th and 5th cervical vertebrae (DAVIDS, 1952, p. 536).

(16) On the occipital plane to the larger ventral half of the crista occipitalis, part of the lateral part of the musculus splenius capitis in *Anas platyrhyncha platyrhyncha* (L.) is attached in an aponeurotic way; the entire muscle runs to the dorsal surface of the atlas and to the processus spinosus of the vertebral or central skeleton ("axis") (DAVIDS, 1952, pp. 534, 536).

(17) To a narrow area of attachment (probably crista-shaped), showing the form of a V, open dorsalwards, lying on the caudal border of the processus occipitalis lateralis, the musculus rectus capitis lateralis in *Anas platyrhyncha platyrhyncha* (L.) is attached in an aponeurotic way; this muscle runs to the hypapophyses of the 2nd, 3rd and 4th cervical vertebra (DAVIDS, 1952, pp. 536, 537).

(18) To a weak crista on the caudal wall of the skull in *Phasianus colchicus* L. and in *Perdix perdix* L., just beside the median, an aponeurosis is attached; to this aponeurosis the third up to and including the fifth branch of the lateral part of the musculus rectus capitis superior are attached; this strong and broad aponeurosis is no doubt an external aponeurosis, showing a total loss of one of the walls, as the muscle fibres are attached to its dorsal surface (DEN BOER, 1953, pp. 458-459; personal communication).

(19) The exceedingly heavy, broad latero-caudal cristae in *Rhinoplax vigil* (Forst.) result in a considerable increase of the surface for the attachment of the muscles of the jaw and neck (MANGER CATS — KUENEN, 1961, p. 42).

Examples of a trabecula cum forma prismae quadrangularis or quadrangular prism or ledge (Ad): no examples are given in the literature mentioned.

Examples of a margo rotundatus or rounded ridge (Ae):

(1) To the very narrow ventral ridge of the dentale the strong tangential aponeurosis of the musculus neuro-mandibularis in *Vipera berus* (L.) is attached; this muscle runs to the dorsal part of the cervical region (DULLEMEIJER, 1956a, pp. 27-28; 1956b, pp. 413-414). To this aponeurosis the musculus branchio-mandibularis is also attached, which runs to the ventro-lateral side of the body (DULLEMEIJER, 1956a, p. 29; 1956b, p. 415) and the musculus mylohyoideus, which is attached to the tongue-bone by means of the perichondrium (DULLEMEIJER, 1956a, p. 29; 1956b, p. 415).

Examples of a costa or rib (Ae):

(1) To the lateral surface of the costa, but not on the upper surface of this costa, lying on the lateral end of the caudal arm of the temporal process, the muscle fibres of the musculus trapezius posterior in *Sphaeroides oblongus* (Bloch) are attached; this small costa is directed medially from the lateral pointed part of the triangle which constitutes the area of attachment on the temporal process and which is situated near the ventro-lateral end of this process (SARKAR, 1960, p. 64).

Examples of a pyramis or spina, or pyramid or spine (Bb):

(1) To the ventral spine on the basisphenoid the narrow external aponeurosis of the musculus rectus capitis ventralis major in *Vipera berus* (L.) is attached; this muscle runs

to vertebrae of the cervical region (DULLEMEIJER, 1956a, pp. 34-35; on p. 106 a crista is mentioned for cervical muscles and that the small crista has the appearance of a spina; 1956b, pp. 420-421; on p. 492 the same notes on crista and spina) (see this paper on p. 25).

(2) To the very small spina, lying just laterally of the articulation-knob with the os accessorium and lying under the crista occipitalis, the narrow tendon of the musculus biventer cervicis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached; this muscle shows a very long and thin second tendon; the second venter and muscle ends on the 16th and the 17th vertebra (DULLEMEIJER, 1951, pp. 533/534).

Examples of a conus or spina, or cone or spine (Bb): no examples are given in the literature mentioned.

Examples of a truncated pyramid (Bc): no examples are given in the literature mentioned.

Examples of a truncated cone (Bc): no examples are given in the literature mentioned.

Examples of a semi-nodus or half-knob (Bd):

(1) To the most lateral point of the almost spherical lateral articulation-knob on the most ventro-lateral point of the quadratum, the short aponeurosis of the musculus cervico-mandibularis of *Vipera berus* (L.) is attached; this muscle runs in the caudo-dorsal direction where it is aponeurotically attached to the connective tissue connecting the processus spinosi dorsales (DULLEMEIJER, 1956a, pp. 26-27; 1956b, pp. 412-413).

(2) The rounded lateral side of the condyle of the lower jaw to which the aponeurosis of the musculus cervico-mandibularis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. is attached, is perhaps also a half-knob (DULLEMEIJER, 1959, p. 908).

(3) To the knob-shaped processus of the basisphenoid the tendon of the musculus rectus capitis superior in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is attached (DULLEMEIJER, 1951, pp. 535/536).

(4) To two separated caudal tuberosities which very probably show the shape of an elongated half-knob, lying on the basitemporal plane, the two aponeuroses of the musculus rectus capitis superior in *Anas platyrhyncha platyrhyncha* (L.) are attached (DAVIDS, 1952, p. 537).

(5) To the lateral tuberosity which very probably shows the shape of an elongated half-knob, lying on the basitemporal plane, the aponeurosis of the musculus rectus capitis ventralis in *Anas platyrhyncha platyrhyncha* (L.) is attached (DAVIDS, 1952, p. 537).

Examples of a margo eminens cum acie acuto sive cum acie obtuso or a protruding margin with a sharp or with an obtuse edge (C):

(1) To the broadened maxilla of *Sphaeroides oblongus* (Bloch) which can be called a special case of such a protruding margin, big muscles are attached (SARKAR, 1960, pp. 98-99).

Examples of a not exactly determined process:

(1) To the medial basal part of the processus caudo-lateralis of the transverse crista of the basisphenoid the external aponeurosis of the musculus rectus capitis ventralis minor in

Vipera berus (L.) is laterally attached; these muscle fibres and those which are in a musculous way attached to a large area on the caudo-ventrally facing part of the occiput run to the cervical region (DULLEMEIJER, 1956a, pp. 35-36; on p. 106 a crista is mentioned for cervical muscles and that the small crista has the appearance of a spina; 1956b, pp. 421-422; on p. 492 the same notes on crista and spina; this musculous attachment to the occiput could be on a surface with a slight excavation, see 1956a, p. 106; 1956b, p. 492) (see this paper on p. 25).

(2) The so-called "crista occipitalis" in *Phasianus colchicus* L., and in *Perdix perdix* L. does not show the character of a crista in our sense of a stereometric figure. This "crista occipitalis" is defined as the whole of the lateral and dorsal border of the caudal surface of the skull ending ventrally in the knob on the basisphenoid (DEN BOER, 1953, p. 338). In *Phasianus* the place of attachment of the musculus complexus is almost entirely restricted to the "crista occipitalis" itself and extends very little on the occipitale in the direction of the foramen magnum; the area of attachment is about "linear"; on this "crista" the attachment extends from the dorsal median latero-ventrally as far as the level of the foramen magnum in caudal view. In *Perdix* the place of attachment on the skull often extends further medialwards on the occipitale in the direction of the foramen magnum beyond the "crista occipitalis". In *Perdix* the ventral border of this place of attachment is often marked by a faint costa which is absent in *Phasianus*; in *Perdix* it is the demarcation between the area of attachment of the musculus complexus and that of the musculus splenius capitis (DEN BOER, 1953, pp. 340-341, 472).

(3) To the most ventral part of this so-called "crista occipitalis" in *Phasianus colchicus* L. and in *Perdix perdix* L. the musculus rectus capitis lateralis is attached; it occurs by means of a weak aponeurosis which is probably an external one, as the muscle fibres are attached on its median surface; the area of attachment to the skull is about "linear" (DEN BOER, 1953, pp. 456, 472; personal communication).

(β) (β) Sinkings or hollowings in the surface

As to these sinkings or hollowings in the surface five sorts which we could define play a part in the attachment of muscles, *viz.* the groove (fossa) (Ga), the impression (impressio) (Gb), the groove or furrow (sulcus) (Gc), the bowl or ball-shaped pit (pelvis) (H) and the sinus (sinus) (I).

Examples of a fossa or groove (Ga):

(1) The area of attachment of the musculus geniohyoideus pars anterior in *Sphaeroides oblongus* (Bloch) on the dentale occupies the entire medial surface ventral to costa (3); it is a crescent-shaped groove which extends from a point close to the ventral tip of the dentale up to the angulare; the attachment is musculous over the entire groove; the angle of attachment is about 90° (SARKAR, 1960, pp. 53, 101).

(2) To the groove may be brought the medial part of the small broad excavation lateral to the processus sphenoideus in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., to which the musculus rectus capitis ventralis minor is musculously attached; the place of attachment reaches somewhat more laterally than halfway the distance from medial to lateral; this muscle runs to the hypapophysis of the atlas (DULLEMEIJER, 1959, p. 912).

(3) To the groove may be brought as well the lateral part of the small broad excavation lateral to the processus sphenoideus in *Crotalus atrox* Baird & Girard and in *Crotalus*

terrificus Laur., to which part of the fibres of the musculus longissimus colli lateralis is attached in a musculous way; this lateral part of the excavation is somewhat deeper than the medial part; this muscle runs to the hypapophysei of the 3rd-8th vertebra (DULLEMEIJER, 1959, p. 912).

(4) To the groove may be brought the broad and deep fossa temporalis in *Rhinoplax vigil* (Forst.); this shows an irregular surface which results in a considerable increase of the surface for the attachment of the muscles of the jaw and neck (MANGER CATS — KUENEN, 1961, p. 42).

Examples of an impression (Gb): no examples are given in the literature mentioned.

Examples of a sulcus or a groove or furrow (Gc): no examples are given in the literature mentioned.

Examples of a pelvis or a bowl or ball-shaped pit (H):

(1) To the bowls or ball-shaped pits may be brought the great number of small round pits of 3 mm diameter closely side by side on the dorsal surface of the neurocranium of *Rhinoplax vigil* (Forst.) and especially of its lateral part; in these pits small muscles are attached running to the base of the calami of feathers of the head (MANGER CATS — KUENEN, 1961, p. 10).

Examples of a sinus (I):

(1) To the sinus may be brought the myodomic canal, which in *Pleuronectes platessa* L. *e.g.* consists in a spacious bony tunnel in the base of the skull, into which the two caudally directed cones eventually fuse (the rostral and caudal cones for the eye-muscles are superimposed on the sphere for the eye-ball; the caudal ones contain the space in which the musculi recti move (DE BLOK, 1956, p. 241).

(β) (γ) Very low projections, *etc.*

As to the very low projections, very shallow deepenings and very slight undulations of the surface, four sorts which we could define play a part in the attachment of muscles, *viz.* the line (linea) (J), the field (area) (K), the circular shallow or low spot (locus editus et excavatus tenuis circularis) (L) and the superficial ring (anulus superficialis) (M).

Examples of a linea or line (J): no examples are given in the literature mentioned.

Examples of an area or a field (K):

(1) To a narrow, rather long and very probably flat area, showing no special demarcations on the bony lower jaw, the musculus genio-hyoideus in *Vipera berus* (L.) is attached in a musculous way; this muscle shows at the other end a musculous attachment to the connective tissue around the musculus hyoglossus (DULLEMEIJER, 1956a, p. 31; 1956b, p. 417).

(2) To an area very probably showing no special demarcations, on the first and second cartilaginous ring of the trachea, the musculus tracheohyoideus in *Vipera berus* (L.) is attached in a musculous way; this muscle shows at the other end a musculous attachment to soft parts of the bottom of the mouth (DULLEMEIJER, 1956a, p. 32; 1956b, p. 418).

(3) To an area on a horn of the tongue-bone, very probably without any special demarcation on the skeletal surface, the musculus hyoglossus in *Vipera berus* (L.) is attached, no doubt in a musculous way; at the other end this muscle ends freely in the bifurcated tongue (DULLEMEIJER, 1956a, p. 32; 1956b, p. 418).

(4) To a caudally facing narrow part of the flat triangular area of the occiput caudal to the first and second lobe in the crista, the musculus rectus capitis dorsalis in *Vipera berus* (L.) is attached in a musculous way; these muscle fibres run towards the 2nd vertebra in a converging way (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420); the musculous attachment to the area of the occiput of this cervical muscle could be a surface with a slight excavation, see 1956a, p. 106; 1956b, p. 492).

(5) To a part of the caudally facing part of the occiput which probably has the character of an area, the musculus obliquus capitis in *Vipera berus* (L.) is attached in a musculous way; these muscle fibres run to the 3rd and 4th vertebra (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420; the musculous attachment to the area of the occiput of this cervical muscle could be on a surface with a slight excavation, see 1956a, p. 106; 1956b, p. 492).

(6) To a place, lateral to the place of attachment of the 3rd part of the musculus spinalis capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., a place that does not reach the lateral surface of the cerebral skull, the musculus rectus capitis dorsalis is attached; in my opinion this place of attachment of this small triangular bundle has perhaps the character of a field (DULLEMEIJER, 1959, p. 910).

(7) To a place on the dorso-lateral corner of the occipital surface, ventral to the area of attachment of the musculus longissimus capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur., the musculus obliquus capitis dorsalis shows a musculous attachment; in my opinion this place of attachment has perhaps the character of a field; these muscle fibres run to the lateral surface of the processus spinosi dorsales of the 2nd-5th vertebra (DULLEMEIJER, 1959, p. 911).

Examples of an elevatio or excavatio circularis et tenuis or a circular shallow or low spot (L): no examples are given in the literature mentioned.

Examples of an anulus superficialis or a superficial ring (M): no examples are given in the literature mentioned.

(c) (γ) Functions in addition to those for the attachment of muscles

Among the surface elements for which we indicated examples that are known to have a function in the attachment of muscles, other examples may occur that show other functions, or even show another function or other functions in addition to that of the attachment of muscles. We will illustrate this with a few examples.

The plattum or plate (Aa) is found not only for the use of the attachment of muscles, but also for the use of the skeleton (the neck-shield) and of the intestinal system (the secondary palate).

The crista or crest (Ac) is found not only in the service of the attachment of muscles, but also for the use of the skeleton (ligaments and other connective tissue connections, membranes or sheets; see BURGGRAAF & FUCHS, 1955, pp. 99, 99/100; BAS, 1957, p. 484). Also in *Sphaeroides* *oblongus* (Bloch) it is not true that every crista should have an aponeurotic attachment (SARKAR, 1960, p. 113).

The margo rotundatus or rounded ridge (Ae) is found not only in the service of the attachment of muscles, but also in the service of the nervous system (the surrounding protection of nerves), of the sense organs (the semi-circular canals; MANGER CATS, 1951, p. 194) and of the vascular system (the canalis caroticus).

The costa or rib (Ae) is found not only in the service of the attachment of muscles, but also for the use of the skeleton (attachment of another skeletal element; attachment of connective tissue of articular capsules, see BURGGRAAF & FUCHS, 1955, p. 99).

Examples: (1) The ventral protruding massive cartilaginous ledge, as it is called by MANGER CATS (1951, pp. 298, 299/300), perhaps acts as a support for the hyomandibulare and for the attachment of the connective tissue membrane to the hyomandibulare.

The spina or spine, either in the form of a pyramid (Bb), or in that of a cone (Bb), is found not only in the service of the attachment of muscles, but also for the use of the skeleton (attachment of ligaments).

The truncated cone (Bc) is found not only in the service of the attachment of muscles, but also for the use of the skeleton (attachment of ligaments).

The semi-nodus or half-knob (Bd) is found not only in the service of the attachment of muscles, but also for the use of sense organs (bulla auditiva).

The margo eminens cum acie acuto and cum acie obtuso or the protruding margin with a sharp edge (C) and such a margin with an obtuse edge (C), are found not only in the service of the attachment of muscles, but also for the use of the skeleton (attachment of ligaments).

The fossa or groove (Ga) is found not only in the service of the attachment of muscles, but also for the use of electric organs and of glands.

The impression (Gb) is found not only in the service of the attachment of muscles, but also for the use of electric organs and of glands.

The sulcus or groove or furrow (Gc) is found not only in the service of the attachment of muscles, but also for the use of the nervous system (the sulcus facialis) and of the vascular system (the sulcus caroticus).

The pelvis or bowl or ball-shaped pit (H) is found not only in the service of the attachment of muscles, but also for the use of glands and the implantation of feathers.

The sinus (I) is found not only in the service of the attachment of muscles, but also for the use of sense organs (the sinus frontalis, the sinus petrosus).

The elevatio or excavatio circularis et tenuis or the circular shallow or low spot (L) is found not only in the service of the attachment of muscles, but also for the use of glands.

The anulus superficialis or superficial ring (M) is found not only in the service of the attachment of muscles, but also for the use of the nervous system (surrounding protection of nerves) and of the vascular system (surrounding protection of blood vessels).

In each of the above-mentioned sixteen main types or sub-types of elements or spots of the surface of the carrying surface we find examples in the service of the attachment of muscles, others being for another use and still others perhaps with a double or multiple function.

There are, however, also main tvpes or sub-types of elements or spots of the surface of the carrying surface which are apparently only for the use of the attachment of muscles. As far as I know this is the case with: the quadrangular prism or ledge (Ad), the truncated pyramid (Bc), the line (J) and the field (K): together, therefore, four main types or sub-types of elements or spots on the surface of the carrying surface.

(c) (δ) Summarizing survey of the elements of the surface for the attachment of muscles

We have taken (see p. 20) as a standard three main forms of the surface of the skull with its projections, deepenings and undulations. These are, as we indicated, the smooth flat surface, the crista and the spina.

It is clear that with respect to the places of attachment of muscles many other conditions occur in nature. The smooth flat surface can have the form of a plane, it can be convex, it can also be concave. With these three sub-types and the sixteen plus the five main types or sub-types, mentioned above, we have twenty-four conditions occurring in nature with all sorts of transitions among them. They are:

a. The smooth flat surface shows the standard form, *i.e.* of a plane. The surface of attachment of the muscle may coincide with this plane, but it may also form a part of the plane, and, finally, the plane may form a part of the more extensive plane-shaped surface of attachment of the muscle.

b. The smooth flat surface may be a smooth convex surface instead of a plane surface. The surface of attachment of the muscle may coincide with the smooth convex surface, but it may also form a part of the smooth convex surface and, finally, the smooth convex surface may form a part of the more extensive convex surface of attachment of the muscle. Such a smooth convex surface may present itself as a slightly high rounded ridge (Ae), as a rib (Ae), as a truncated cone (Bc), as a half-knob (Bd), a definition of which was given above. The shape of such a smooth convex surface can vary a great deal, and depends on the outline and the height of the bulging surface-element. The position of the bulging protuberance in regard to the surrounding plane can also vary greatly, which becomes manifest in the position of the axis of the protuberance, situated in its centre, in regard to the carrying surface, which position can vary between a vertical and a very slanting position.

Examples: (1) The musculous attachment of the musculus cucullaris in *Rana esculenta* L. to the cartilage of the ventral plane of the squamosum in my opinion very probably takes place on a rounded, convex place of attachment (Cool, 1952, pp. 641/642, fig. 1 on p. 636).

(2) The musculous attachment of the musculus intertransversarius capitis inferior in *Rana esculenta* L. to the exoccipitale and its neighbourhood in my opinion probably takes place on a convex surface of attachment on the exoccipitale and on the cartilage lying laterally of it (Cool, 1952, p. 642).

c. The smooth flat surface can be a smooth concave surface, instead of a plane surface and a convex surface. The surface of attachment of the muscle can coincide with the smooth concave surface, but it can also form a part of the smooth concave surface and, finally, the smooth concave surface can form a part of the more extensive concave surface of attachment of the muscle. Such a smooth concave surface can present itself as a shallow groove (Ga), as an impression (Gb), as a groove or furrow (Gc), as a bowl or ball-shaped pit (H), as a shallow field (K) and as a circular shallow spot (L), a definition of which was given above. Such a smooth concave surface can vary a great deal in shape, dependent on the outline and the depth of the hollow surface-element. The depth of a groove or its shallowness depends on the number of muscle fibres attached to it and also on the direction of their working lines (Sarkar, 1960, p. 103 on the slopes of the grooved areas on the praefrontale and the squamosum in *Sphaeroides oblongus* (Bloch)).

The position of the sinking in regard to the surrounding plane can also be most diverse, which manifests itself in the position of the axis of the sinking, situated in its centre, in regard to the carrying surface, which position can vary between a vertical position and a very slanting one.

Examples: (1) The surface of muscular attachment of the musculi coraco-arcuales III and IV to the hypobranchiale III and IV with the adjoining parts of the ceratobranchiale III and IV in *Squalus acanthias* L. is part of a plane which in a horizontal projection is hollow and which in a vertical projection is flat; the musculus coraco-arcualis II shows a musculous attachment to the hypobranchiale II only (Van den Assem, 1952, pp. 666, 667).

(2) The attachment of the most rostral muscle fibres of the musculi intercrurales in *Rana esculenta* L. lies in a fossa of the exoccipitale; the ventral border runs nearly along the dorsal plane of a crista on the surface of the exoccipitale (Cool, 1952, p. 641).

(3) The surface of musculous attachment of most of the muscle fibres of the musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is an undeep depression, containing at its medial part an undeep conical depression, on the occipital surface of the skull (Dullemeijer, 1951, pp. 534/535).

(4) To the surface of the small flat area which is sometimes a little depressed, the musculous attachment of the musculus rectus capitis superior in *Phalacrocorax carbo sinensis* (Shaw & Nodder) takes place (Dullemeijer, 1951, pp. 535-536).

(5) To the surface of the triangular area on the ventral surface of the skull, which area is somewhat depressed in the central part, the musculous attachment of the musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) takes place (DULLEMEIJER, 1951, p. 536).

(6) The surface of musculous attachment of the musculus biventer cervicis in *Phasianus colchicus* L. is a short, shallow but clearly visible excavation just laterally from the median and directly ventrally of the attachment of the musculus complexus and running about parallel to the dorso-medial part of the "crista occipitalis". In *Perdix perdix* L. this is very similar to that in *Phasianus*; however, as a consequence of the stronger development of the musculus complexus in *Perdix*, the above-mentioned excavations are situated more ventrally in relation to the "crista occipitalis" (DEN BOER, 1953, pp. 342-343).

(7) The place of musculous attachment of the 1st and 2nd branch of the lateral part of the musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. is situated in a faint excavation directly dorsal of the place of attachment of the aponeurosis to which the other branches of this lateral part of the muscle are attached (DEN BOER, 1953, p. 459).

d. Protuberant elements or spots, such as a rounded ridge (Ae), a rib (Ae), a truncated cone (Bc) and a half-knob (Bd), can sometimes be considered as a smooth convex surface, as we have seen above. In other examples this is not the case. We also find many variations with regard to the shape, dependent on the outline and the height of these surface-elements, and with regard to the position of the protuberance, which becomes manifest in the position of the axis of the protuberance in regard to the carrying surface (vertical or very slanting position).

e. The remaining protuberant elements or spots, to which muscles are attached, are the plate (Aa), the crest (Ac), the rafter with the form of a quadrangular prism or the ledge (Ad), the pyramid-shaped spine (Bb), the cone-shaped spine (Bb), the truncated pyramid (Bc), and the two protruding margins with the sharp and with the obtuse edge (C). Of all these types we have taken the crest and the spine as standard forms. All these eight protuberant elements can vary greatly in their shape as well as in their position. The shape varies dependent on the relation of the height to the length and the breadth of the base and varies in connection with the absolute measures of these axes. The position can be greatly diversified in relation to the carrying surface.

f. The different types of sinkings, such as the groove (Ga), the impression (Gb), the groove or furrow (Gc), the bowl or ball-shaped pit (H) and the sinus (I), vary greatly in their shape as well as in their position.

g. The very low projections, the very shallow deepenings and the very slight undulations of the surface of the skull, to which muscles are attached, and which deviate from the general surface of the carrying surface to such a small extent, that we can neither markedly allocate them to the protuberances, nor markedly to the sinkings, such as the line (J), the field (K), the circular shallow or low spot (L) and the superficial ring (M), can vary a great deal as to their shape and size.

h. The surface of attachment of muscles to the skull can be a combination of two or more variations within one main form of the surface of the skull, so within the smooth flat surface with its variations of a plane, a convex and a concave surface; the result of such a complex area of attachment is a curved or accidented plane (Cool, 1953, p. 243).

Examples: (1) The musculous attachment of the musculus coraco-hyoideus in *Squalus acanthias* L. to the copula of the hyoid contains a slightly curved surface which is ventral-facing and a very narrow, no doubt plane, caudal-facing surface of the copula which stands almost perpendicularly to the large ventral-facing surface (Van den Assem, 1952, p. 661)

i. The surface of attachment of muscles to the skull can be a combination of two or three main forms of the surface of the skull with its projections, deepenings and undulations, so of a smooth surface of the skull with a crista and/or with a fossa.

Examples: (1) The surface of attachment of the muscle fibres and of the aponeuroses of the musculus dorsolateralis in Squaliformes on the regio occipitalis consists of three different parts:

1) a smooth plane surface on the dorsal plane of the regio occipitalis on both sides of the crista occipitalis,

2) a part of the surface of the rounded ridge over the canalis semicircularis anterior and posterior and in *Scylliorhinus* also along the rounded ridge of the canalis semicircularis horizontalis, and

3) the shallow concave fossa in the corner between the rounded ridges of the two vertical canales semicirculares in *Mustelus* and *Scylliorhinus* (in *Squalus* this area is not concave) (Manger Cats, 1951, pp. 196-199).

(2) The surface of attachment of the muscle fibres of the musculus coraco-arcualis V in *Mustelus* takes place on a flat cardiobranchiale and on an area of the ceratobranchiale V which in *Mustelus* shows a distinct furrow which is absent in *Squalus* (Van den Assem, 1952, p. 668).

(3) The surface of attachment of the antagonist of the musculus dorsolateralis in *Raja batis* L. to the skull shows a convex surface on the medial and lateral surfaces of the condylus lateralis; it shows a shallow rounded groove or excavation and a concave surface lying between the condylus lateralis, the foramen nervi glossopharyngei and the foramen surrounded by the rod γ (read α), and it shows a triangular surface on the condylus lateralis and a surface directly laterally and medially of it (to this the aponeurosis is attached which passes into the perichondrium covering the rostro-medially directed rounded ridge on the ventral surface of the skull) (Gottenbos, 1956, pp. 730, 732, 733).

(4) The musculous and aponeurotic attachments of the musculus supracranialis in *Sphaeroides oblongus* (Bloch) take place to the caudal rim of the posterior projection of the occipital spine (first portion of the muscle), to the small spine on the dorsal surface of the parietale and to the base of the occipital spine (second portion), to another aponeurosis (third portion), to the ventral ridge of the occipital spine and to the lateral surface of the

occipital spine (fourth portion) and to the triangular surface on the cerebral skull ventral to the occipital spine, to the rounded posterior surface of the parietale, to the paired pointed spinous structure present at the junction of the base of the postfrontale and the parietale and again to another aponeurosis (fifth portion) (SARKAR, 1960, pp. 71-73).

(5) The musculous and aponeurotic attachment of the musculus longissimus dorsi in *Rana esculenta* L. to the caudal wall of the skull in the first place takes place in a musculous way to the shallow fossa on the caudal surface of the fronto-parietale lying between a crista on the fronto-parietale, the border of the muscle running at a short distance parallel to this crista; in the second place in a musculous way to the low costa, separating exoccipitale and fronto-parietale; in the third place to the rounded cartilaginous ridge, formed by the synchondrosis prootico-exoccipitalis, to which a short aponeurosis is tangentially attached and perhaps also a musculous attachment takes place; in the fourth place in a musculous way perhaps for a small part to the dorsal fossa on the exoccipitale, ventrally of the fronto-parietale (COOL, 1952, pp. 640/641).

(6) The aponeurotic and musculous attachment of the musculus intertransversarius capitis superior in *Rana esculenta* L. to the caudal wall of the skull in the first place takes place with a rather long aponeurosis attached to the whole crista of the exoccipitale, in the second place in a musculous way to the rounded cartilaginous ridge of the synchondrosis prootico-exoccipitalis and in the third place perhaps also on the edge of the fossa on the exoccipitale (COOL, 1952, p. 641).

(7) The musculous and aponeurotic attachment of the musculus levator scapulae superior in *Rana esculenta* L. to the operculum and to the cartilage in its neighbourhood in the first place takes place in a musculous way to the in my opinion probably plane surface of the operculum, in the second place by means of a short aponeurosis, which is tangentially attached to the in my opinion probably convex surface of the cartilage which lies laterally and latero-ventrally of the operculum, the surface of the cartilage bending rostralwards on this place of attachment and in the third place in a musculous way for the greater part in a fossa ventrally of the operculum, the area of attachment extending medio-ventrally and medially of the operculum (COOL, 1952, p. 642).

(8) The aponeurotic and musculous attachment of the musculus rhomboideus anterior in *Rana esculenta* L. to the fronto-parietale in the first place takes place with a short aponeurosis to the caudal surface of a crista on the fronto-parietale, in the second place with a short aponeurosis to the caudal part of another crista on the fronto-parietale and in the third place in a musculous way on the in my opinion probably plane surface of the fronto-parietale (COOL, 1952, p. 643).

(iii) (3) Course of the muscle fibres

(3) (a) Introduction

With regard to the course of the muscle fibres, we have described above as a standard the condition that, firstly, the muscle fibres run parallel or nearly parallel to each other and, secondly, that they are perpendicular to skeletal surfaces carrying the places of muscle-attachment.

On both points we find many deviations from this standard in nature, of which we will mention and discuss not all the deviations and not all allied forms, but a number of them only.

For a clear comprehension of both points, it is necessary to mention that we have to base the features of the course of the muscle fibres of these muscles which are of interest for our purpose on account of (α) the general topography of the muscle, on the following characters of shape and attachment of the muscles determining the course of the muscle fibres: (β) the external shape of the muscle with regard to the composition of the muscle, (β2) the external shape of the muscle and its branches with regard to the course of the axis of a simple muscle or of the branches of a muscle, (β3) the structure of the muscle with regard to the topographical relation of the muscle fibres in their attachment to the skeleton whether or not through the medium of aponeuroses, and (β4) the way of attachment of the head muscles.

(a) (α) Muscles of interest for our purpose on account of the general topography of the muscle

As to the topography of the muscle it is of interest for our purpose whether the muscle lies entirely or partly in the head. In this respect we may distinguish the following types of muscles (see also VAN DER KLAAUW, 1952, p. 371, classification and sequence changed here):

(α) i) Muscles lying entirely within the head, attached to the skull at both ends

Within this type the following sub-types can be distinguished:

α) Muscles which run on the left side of the skull as well as on its right side, connecting corresponding skull elements of the left and of the right side, without an intermediate aponeurosis or tendon in the median plane; the muscle fibres run in a more or less transverse direction.

Examples: (1) The right and left part of the muscle in the floor of the buccal cavity in *Raja batis* L., starting from the hyomandibulare, end in this floor without attachment to a skeletal part or to an aponeurosis in the median (GOTTENBOS, 1956, p. 553).

(2) The unpaired musculus intermandibularis superficialis in *Ondatra zibethica* (L.) connects the two halves of the skeletal lower jaw caudally of the symphysis and dorsally of the musculus digastricus; the length of the muscle is about 4 mm, its width is about 2 mm; immediately caudally of the crista (15) the ventral surface of the lower jaw curves medio-dorsalwards; here the muscle fibres are musculously attached to the bone of the lower jaw (VAN VENDELOO, 1953, p. 270).

β) Muscles which run on the left side of the skull as well as on its right side, connecting corresponding skull elements of the left and of the right side, showing an intermediate aponeurosis or tendon in the median plane; the muscle fibres run in a more or less transverse direction.

Examples. (1) The musculus adductor arcus palatini in *Sphaeroides oblongus* (Bloch) shows a fusion of the left and right muscle in its rostral part; the fibres of the fused part of the muscle run transversely from the palatinum of one side to the same bone of the other side; the muscle fibres from both sides are connected to an aponeurosis in the median line (SARKAR, 1960, pp. 44-45).

(2) The right and left musculus mylohyoideus anterior in *Phasianus colchicus* L., which lie in the floor of the mouth cavity, are connected in the median line by a thin horizontal rostro-caudally directed aponeurosis (23); this paired muscle lies between the rostral parts of the two halves of the skeletal lower jaw; they are musculously attached to the medial surface of the skeletal lower jaw along a narrow strip; the area of attachment does not show any special surface structures; the muscle fibres run in a caudo-medial direction to aponeurosis (23); rostrally this aponeurosis (23) is attached to crista (23) on the lower jaw; this crista (23) constitutes the caudal rim of the medial plate of the lower jaw (BURGGRAAF, 1954, pp. 673-675).

(3) The right and left musculus serpihyoideus in *Phasianus colchicus* L., which lie in the floor of the mouth cavity, are connected in the median line by the caudal part of the thin horizontal rostro-caudally directed aponeurosis (23); this paired muscle lies between the caudal parts of the right and left processus retro-articularis; each half is musculously attached to the ventral edge and to the ventral part of the lateral surface just rostrally of the laterally curved caudal end of this processus and curving ventralwards proceeds in a medio-rostral direction (BURGGRAAF, 1954, pp. 675-676).

γ) Muscles which run on the left side of the skull as well as on its right side, connecting skull elements lying one behind the other, without an aponeurosis or tendon in the median plane; the muscle fibres run in a more or less parasagittal direction.

Examples: (1) The muscle fibres of the musculus geniohyoideus, pars anterior in *Sphaeroides oblongus* (Bloch) run in a straight antero-posterior direction almost parallel to each other, starting from the dentale; a distinct separation in the median is absent; the muscles of the two sides look like a single rectangular muscle (SARKAR, 1960, p. 53).

(2) In the dorsal part of the musculus hyohyoideus ventralis of *Sphaeroides oblongus* (Bloch) anteriorly the dorsal parts of the muscles of the right and the left sides are fused to appear like a single muscle; they unite at the dorsal surfaces of the hypo- and the ceratohyalia; dorso-medially directed muscle fibres are fused with similar muscle fibres coming from the opposite side, just over the slender urohyale; anterior muscle fibres of a portion of the dorsal part which is also attached to the dorsal surface of the wing-like expansion in the region of the branchiostegal rays, run in the same dorso-medial direction and meet the muscle fibres of the other side on the median unpaired basi-branchiale (SARKAR, 1960, pp. 56-57).

(3) In its rostral part the musculus digastricus in *Ondatra zibethica* (L.) is unpaired; this rostral part of the muscle runs from the skeletal lower jaw; the muscle fibres run in a parasagittal direction (VAN VENDELOO, 1953, p. 268).

δ) Muscles which run on the left side of the skull as well as on its right side, connecting skull elements lying one behind the other, showing an intermediate aponeurosis or tendon in the median plane; the muscle fibres run in a more or less parasagittal direction.

No examples are given in the literature mentioned.

ε) Muscles which run on the left side of the skull as well as on its right side, connecting skull elements lying one behind the other, the left and the right muscle lying at a certain distance from each other and from the median plane.

For examples see the separate paragraph (6) at the end of this chapter (I) on the descriptive-anatomical examination.

The first-mentioned two sub-types (α and β) are treated here as one muscle connecting corresponding skull elements of the left and of the right side; these two sub-types might be considered as well as muscles running from the skull to soft parts of the head, the aponeurosis or tendon being considered as a soft part, but this will not be done here by us.

The mentioned skeletal attachments can appear entirely or partly as a skeletal attachment at one or at both ends of the muscle. The same character can be shown by the attachment to the skull in the types ii), iv) and v).

(*a*) ii) Muscles lying entirely within the head, attached at one end to the skull and at the other end to soft parts of the head

α) Muscles which run on the left side of the skull as well as on its right side, connecting a skull element with a soft part of the head near the median plane of the head; the muscle fibres run in a more or less transverse direction.

Examples: (1) In the musculus depressor hyomandibularis in *Raja batis* L. the muscle fibres of right and left muscle, starting from the hyomandibulare, are contiguous in the median; the angle they make with the median varies from 90° (the most rostral fibres) to 40° (the most caudal ones); most of these fibres or perhaps all show an attachment to the fascia of the pericardium, which acts as an external aponeurosis with the dorsal surface of which the muscle fibres make an angle of one or a few degrees (GOTTENBOS, 1956, pp. 551-552).

β) Muscles which run on the left side of the skull as well as on its right side, connecting a skull element with a soft part of the head, the left and the right muscle lying at a certain distance from each other and from the median plane.

Examples: (1) Certain muscles in Squaliformes are at one end attached to the skin of the head (MANGER CATS, 1951, p. 192).

(2) The musculus levator palpebrae nictitantis in *Mustelus* and in *Scylliorhinus* shows an attachment on the lower eyelid and a muscular attachment to the regio otica of the skull; in *Mustelus* this small area of attachment is a shallow concavity on the dorso-caudal part of the regio otica, in *Scylliorhinus* it lies in a rounding of the skull at the back (MANGER CATS, 1951, pp. 201, 297/298, 300).

(3) The part A_1 and a small part of $A_{2,3}$ of the musculus adductor mandibulae in *Pleuronectes platessa* L., having its origin on the skull, is partly inserted on the ligamentum maxillo-mandibulare; this muscle will keep the ligamenta maxillo-mandibularia under tension in resisting the pressure exercised upon the upper jaw when the mouth is opened; the left ligamentum maxillo-mandibulare effects the protrusion of the upper jaw apparatus, which itself lacks attachments of muscles, the movements of the upper jaw apparatus

being brought about by the movements of other elements (technique of the jumping-jack) (De Blok, 1957, pp. 82, 83, 88/89).

(4) The musculus geniohyoideus pars anterior in *Sphaeroides oblongus* (Bloch) runs from the dentale to a connective tissue plate standing crosswise on a level with the angularia (Sarkar, 1960, p. 53).

(5) The musculus geniohyoideus in *Vipera berus* (L.) runs from the lower jaw to the connective tissue around the musculus hyoglossus (Dullemeijer, 1956a, p. 31; 1956b, p. 417).

(6) The musculus tracheo-hyoideus in *Vipera berus* (L.) runs from the trachea to the bottom of the mouth and the connective tissue medial to the musculus branchio-mandibularis; the connective tissue in the bottom of the mouth envelops the tongue-bone (Dullemeijer, 1956a, p. 32; 1956b, p. 418; personal communication).

(7) The musculus hyoglossus in *Vipera berus* (L.) runs from a horn of the tongue-bone to the free point of the tongue (Dullemeijer, 1956a, p. 32; 1956b, p. 418).

(8) The musculus mylohyoideus anterior of *Anas platyrhyncha platyrhyncha* (L.) shows a small sagittal plate of connective tissue to which the muscle fibres are attached which start from the medial side of the lower jaw and which run in a ventro-medial direction (Davids, 1952, p. 538).

(9) A thin skin muscle in *Anas platyrhyncha platyrhyncha* (L.) runs from a narrow area on the neurocranium at the height of the cavum tympanicum towards the skin (Davids, 1952, p. 538).

(10) Small muscles run from small round pits lying on the dorsal surface of the neurocranium of *Rhinoplax vigil* (Forst.) and especially from its lateral part to a point near the base of calami of feathers on the head (Manger Cats — Kuenen, 1961, p. 42).

(α) iii) Muscles lying entirely within the head, attached at both ends to soft parts of the head

These muscles may run from one place to another at the left as well as at the right side of the head, or they may run from the left side to the right side of the head.

No examples are given in the literature mentioned.

(α) iv) Muscles lying partly within the head and attached with this end entirely or partly to the skull, and partly in the body outside the head and attached with that end of the muscle entirely or partly to the skeleton in the body

α) Muscles which run on the left side of the skull as well as on its right side, connecting a skull element with an element of the skeleton of the body, without an aponeurosis or tendon in the median plane; the muscle fibres run in a more or less parasagittal direction.

Examples: (1) The muscle fibres of the left and the right musculus sternohyoideus in *Sphaeroides oblongus* (Bloch) run next to each other, reaching each other in the median plane, without an aponeurosis in the median plane; this muscle of each side is covered by a common connective tissue plate so that they look like a single muscle; they can be separated from each other posteriorly after removing the connective tissue plate; anteriorly the left and the right muscle are attached by a common aponeurosis (24) to the cerato-hyalia and the hypohyalia at an angle of 45°; at a short distance from the place of attachment the common aponeurosis (24) divides into two superficial aponeuroses, one for each muscle (SARKAR, 1960, p. 61).

(2) The medial limit between the right and the left part of the musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder), running from the occipital region to the 2nd and the 3rd vertebra, could not be determined (DULLEMEIJER, 1951, pp. 534/535).

(3) The medial limit between the right and the left part of the musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder), running from the ventral surface of the skull to the 1st-6th vertebrae, could not be determined (DULLEMEIJER, 1951, p. 536).

(4) In the rostral part of the musculus complexus in *Phasianus colchicus* L. and in *Perdix perdix* L., running from the 3rd and 4th vertebra to the caudal wall of the skull, which part lies in the head, the muscle fibres of right and left muscle are contiguous in the median; in *Phasianus* right and left muscle are connected with each other in the median only over a short distance in the most rostral part and in some cases they are not connected at all; in *Perdix* the right and left musculi complexi are fused in the median over a much greater distance from the most rostral point than in *Phasianus* (DEN BOER, 1953, pp. 339, 341).

(5) In the rostral part of the musculus rectus capitis ventralis in *Phasianus colchicus* L., running from the basisphenoid to the 1st up to and including the 6th vertebrae, the powerful medial parts of the right and left muscle are firmly connected with each other in the median, so that in many specimens the right and left muscles are not clearly distinct from each other (DEN BOER, 1953, p. 459).

β) Muscles which run on the left side of the skull as wel as on its right side, connecting a skull element with an element of the body, the left and the right muscle lying at a certain distance from each other and from the median plane.

Examples: (1) The musculus coraco-arcualis V in *Squalus* of which one end is attached to the skull, is at the other end attached to the pectoral girdle (VAN DEN ASSEM, 1952, pp. 668/669).

(2) The antagonist of the musculus dorsolateralis in *Raja batis* L. of which one end is attached to the regio occipitalis of the skull is at the other end of the muscle attached to the vertebral trough and to the connective tissue sheet covering the musculus dorsolateralis (GOTTENBOS, 1956, pp. 730/731).

(3) The musculus sternohyoideus in *Sphaeroides oblongus* (Bloch), at one end attached to the rostro-medial border of the ceratohyale and to the caudal edge of the hypohyale, runs in an antero-posterior direction to the narrow anterior end of the cleithrum (SARKAR, 1960, p. 61).

(4) The musculus trapezius anterior in *Sphaeroides oblongus* (Bloch), at one end attached to the posterior surface of the rostral arm of the temporal process, runs to the ventro-lateral part of the cleithrum and to the anterior surface of the supracleithrum (SARKAR, 1960, pp. 62-63).

(5) The musculus trapezius posterior in *Sphaeroides oblongus* (Bloch), at one end

dorso-medially attached to the posterior arm of the temporal process, runs to the caudo-dorsal projection of the cleithrum (SARKAR, 1960, p. 64).

(6) The musculus supracranialis in *Sphaeroides oblongus* (Bloch) runs from the occipital region and the parietale to the vertebrae *etc.* of the body; in portion 1 of this muscle the two bundles lying closely together along the mid-dorsal line of the head run directly in a posterior direction; the posterior end of portion 2 which runs lateral to portion 1 is not indicated; in portion 3 of this muscle the muscle fibres run straight caudally to the region of the 3rd vertebra; in portion 4 of this muscle at the posterior end the muscle fibres are attached to aponeurosis (38), almost in the same line to the anterior surface of the neural spine of the 4th vertebra, while other muscle fibres are attached to the neural spines of the 1st, 2nd and 3rd vertebra; in portion 5 we find attachments outside the skull to the cleithrum, but also at the posterior end caudal attachments to the entire lateral surface of the vertebral column (SARKAR, 1960, pp. 71-73).

(7) The musculus rectus capitis dorsalis in *Vipera berus* (L.) runs from the occiput to the processus spinosus dorsalis of the 2nd vertebra (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420).

(8) The musculus obliquus capitis in *Vipera berus* (L.) runs from the occiput to the processus spinosi dorsales of the 3rd and 4th vertebra (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420).

(9) The musculus rectus capitis ventralis major in *Vipera berus* (L.) runs from the basisphenoid to the hypapophyses of the 1st to and including the 10th vertebra and the connective tissue between the hypapophyses (DULLEMEIJER, 1956a, pp. 34-35; 1956b, pp. 420-421).

(10) The musculus rectus capitis ventralis minor in *Vipera berus* (L.) runs from the occiput to the hypapophyses and the connective tissue between these processus from the 1st to and including the 5th vertebra; on the 1st and the 2nd vertebra the attachment reaches the pleurapophysis (DULLEMEIJER, 1956a, p. 35; 1956b, p. 421).

(11) The musculus spinalis capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs from the occiput caudalwards and is attached partly to the dorso-lateral surface of the processus spinosus dorsalis of the 3rd, 4th and 9th vertebra, partly to the fascia of the musculus spinalis (DULLEMEIJER, 1959, p. 910).

(12) The musculus longissimus capitis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs from the crista occipitalis to the ventro-medial surface of the processus spinosi dorsales of the 6th-15th vertebra (DULLEMEIJER, 1959, p. 911).

(13) The musculus obliquus capitis dorsalis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs from the occipital surface to the lateral surfaces of the processus spinosi dorsales of the 2nd-5th vertebra (DULLEMEIJER, 1959, p. 911).

(14) The musculus rectus capitis ventralis major in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs from the processus sphenoideus to the hypapophysei of the 3rd-26th vertebra (DULLEMEIJER, 1959, p. 911).

(15) The fibres of the musculus rectus capitis ventralis minor in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. converge from the excavation lateral to the processus sphenoideus to a short aponeurosis on the rostral side of the hypapophysis of the atlas (DULLEMEIJER, 1959, p. 912).

(16) The musculus longissimus colli lateralis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs from an area on the cerebral skull lateral to the processus sphenoideus to the 3rd-8th vertebra (DULLEMEIJER, 1959, p. 912).

(17) The musculus complexus in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the occipital surface of the skull to the 3rd, 4th and 6th vertebra (DULLEMEIJER, 1951, p. 533).

(18) The musculus biventer cervicis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the occipital surface of the skull to the 16th and the 17th vertebra (DULLEMEIJER, 1951, pp. 533/534).

(19) The musculus splenius capitis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the occipital surface of the skull to the 2nd and 3rd vertebra (DULLEMEIJER, 1951, pp. 534/535).

(20) The musculus rectus capitis superior in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the basisphenoid to the 1st-5th vertebra (DULLEMEIJER, 1951, pp. 535/536).

(21) The musculus rectus capitis lateralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the squamosum to the 2nd-5th vertebra (DULLEMEIJER, 1951, p. 536).

(22) The musculus rectus capitis ventralis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) runs from the ventral surface of the skull to the 1st-6th vertebra (DULLEMEIJER, 1951, p. 536).

(23) The musculus biventer cervicis in *Anas platyrhyncha platyrhyncha* (L.) runs from the crista on the caudal surface of the occipital plane to the base of the neck (DAVIDS, 1952, pp. 534-536).

(24) The musculus complexus in *Anas platyrhyncha platyrhyncha* (L.) runs from the larger part of the dorsal half of the strong crista occipitalis lying on the caudal surface of the occipital plane and from a small and short area of musculous attachment at the dorsal end of this aponeurotic attachment to the lateral surfaces of the 3rd, 4th and 5th cervical vertebra (DAVIDS, 1952, p. 536).

(25) The musculus rectus capitis superior in *Anas platyrhyncha platyrhyncha* (L.) runs from the tuberosities of the basitemporal plane to the lateral surfaces of the 1st, 2nd, 3rd, 4th and 5th cervical vertebra (DAVIDS, 1952, p. 537).

(26) The musculus rectus capitis ventralis in *Anas platyrhyncha platyrhyncha* (L.) runs from the surface of the basitemporal plane (with the exception of the crown of the oblong bulla in the median line) and runs from the lateral tuberosities on this basitemporal plane towards the ventral surface of the atlas and the hypapophysis of the vertebral or central skeleton ("axis") and towards the hypapophyses of the 3rd, 4th, 5th and 6th cervical vertebrae (DAVIDS, 1952, p. 537).

(27) The musculus complexus in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal vertical surface of the so-called "crista occipitalis" on the caudal wall of the skull to the 3rd and 4th cervical vertebrae (DEN BOER, 1953, pp. 339-341). As the relation breadth/height of the caudal surface of the skull in *Perdix* is definitely greater than in *Phasianus*, the area of attachment of the musculus complexus extends relatively farther lateralwards in *Perdix* than in *Phasianus* (DEN BOER, 1953, p. 341).

(28) The musculus biventer cervicis in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull to the region of the cervical vertebrae (DEN BOER, 1953, pp. 341-343).

(29) The musculus splenius capitis in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull to the 2nd cervical vertebra; a few muscle fibres in *Phasianus* attached very far ventrally upon the skull, are attached with the other end to

the connective tissue membrane round the foramen magnum instead of to the epistropheus (DEN BOER, 1953, pp. 343, 344).

(30) The musculus rectus capitis lateralis in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull to the 2nd, 3rd and 4th cervical vertebrae (DEN BOER, 1953, p. 455).

(31) The musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull with a medial part with 3 branches and a lateral part with 5 branches to the 1st up to and including the 5th cervical vertebra (DEN BOER, 1953, pp. 456, 457).

(32) The musculus rectus capitis ventralis in *Phasianus colchicus* L., which seen from the ventral side is a large about triangular muscle, runs from the knob on the basisphenoid with its large medial part to the 1st up to and including the 4th cervical vertebrae and with its smaller lateral part to the 5th and 6th cervical vertebra. In *Perdix perdix* L. the medial part runs to the 1st up to and including the 5th cervical vertebra and the minute lateral part runs to the 6th cervical vertebra only (DEN BOER, 1953, pp. 459-462, 465-466).

(α) v) Muscles lying partly within the head and attached with this end entirely or partly to the skull, and partly in the body outside the head and attached with that end of the muscle to soft parts of the body

Examples: (1) The musculus coraco-hyoideus in *Squalus acanthias* L., starting from the hyoid arch, shows an attachment to the solid central aponeurosis system (this aponeurosis system is not directly attached to the skeleton, but by means of the musculus coracoideus to the pectoral girdle) (VAN DEN ASSEM, 1952, pp. 657, 661).

(2) The musculus coraco-arcualis I in *Squalus acanthias* L., starting from the hyoid arch, shows an attachment to the solid central aponeurosis system, mentioned above (VAN DEN ASSEM, 1952, p. 662).

(3) The musculi coraco-arcuales II-IV in *Squalus acanthias* L., starting from the 2nd, 3rd and 4th branchial arch, show attachments to the half-dome shaped cupola, being part of the fascia of the pericardium, and to the connection of the cupola with the aponeurosis belonging to the musculus constrictor superficialis (VAN DEN ASSEM, 1952, pp. 658, 660, 664, 666-668).

(4) The musculus depressor hyomandibularis in *Raja batis* L., starting from the hyomandibulare, shows an attachment to the fascia of the pericardium which is attached to the pectoral girdle and to the medial part of an aponeurosis into which this fascia passes (GOTTENBOS, 1956, pp. 551-552, 725, 734).

(5) The musculus retractor quadrati in *Vipera berus* (L.) runs from the quadratum to the skin in the cervical region (DULLEMEIJER, 1956a, p. 25; 1956b, p. 411).

(6) The musculus cervico-mandibularis in *Vipera berus* (L.) runs from the quadratum to the connective tissue connecting the processus spinosi dorsales in the cervical region dorsally to the 5th-7th vertebrae (DULLEMEIJER, 1956a, pp. 26-27; 1956b, pp. 412-413).

(7) The musculus neuro-mandibularis in *Vipera berus* (L.) runs from the skeletal lower jaw to the connective tissue covering the cervical muscles in the median dorsally to the 6th-7th vertebrae (DULLEMEIJER, 1956a, p. 27; 1956b, p. 413).

(8) The musculus branchio-mandibularis in *Vipera berus* (L.) runs from the lower jaw to the ventro-lateral side of the body on the level of the 5th-6th rib, where it is attached

to the connective tissue covering the muscles between the ribs (DULLEMEIJER, 1956a, p. 29; 1956b, p. 415).

(9) The musculus spinalis capitis in *Vipera berus* (L.) runs from the supraoccipitale partly to the most rostral tendon of the musculus spinalis, partly to the connective tissue between the processus spinosi dorsales of the 5th up to and including the 13th vertebra (DULLEMEIJER, 1956a, pp. 32-33; 1956b, pp. 418-419).

(10) The musculus longissimus capitis in *Vipera berus* (L.) runs from the occipital region of the skull to the caudal region of the body, the fascia of the muscle being connected with the dorsal surface of the vertebrae (DULLEMEIJER, 1956a, p. 33; 1956b, p. 419).

(11) The musculus ilio-costalis occipitalis in *Vipera berus* (L.) runs from the exoccipitale to the cauda, dorsally along the processus transversi and laterally along the processus spinosi dorsales (DULLEMEIJER, 1956a, p. 33; 1956b, p. 419).

(12) The musculus longissimus colli lateralis in *Vipera berus* (L.) runs from the occiput caudalwards through the whole body along the latero-dorsal side of the body (DULLEMEIJER, 1956a, p. 34; 1956b, p. 420).

(13) The musculus rectus capitis dorsalis in *Crotalus atrox* Baird & Girard and in *Crotalus terrificus* Laur. runs as a small triangular bundle from the occiput with converging muscle fibres to a line-shaped area in the medial plane on the connective tissue dorsal to the atlas (DULLEMEIJER, 1959, p. 910).

(α) vi) Muscles lying partly within the head and attached with this end to soft parts of the head, and partly in the body outside the head, and attached with that end of the muscle partly or entirely to the skeleton in the body outside the head

Examples: (1) The musculus levator rostri in *Raja batis* L. runs from an aponeurosis in the rostral edge of the head (between the top of the rostrum and the rostral border of the pectoral fin) to the vertebral trough (GOTTENBOS, 1956, p. 723).

(α) vii) Muscles lying partly within the head and attached with this end to soft parts of the head, and partly in the body outside the head, and attached with that end of the muscle to soft parts of the body outside the head

Examples: (1) The musculus depressor rostri in *Raja batis* L. runs from an aponeurosis in the rostral edge of the head to the fascia of the pericardium, to an aponeurosis, into which the fascia of the pericardium passes and to a connective tissue membrane covering the musculus coraco-mandibularis (GOTTENBOS, 1956, pp. 723-726).

The special interest of this paper has to be looked for in the head muscles of type i); the examples of this category are compiled in a separate paragraph (No. (6) on p. 81). The examples of the head muscles of the types ii), iv) and v), muscles that are attached to the skull, at one muscle-end only, are classed into the point or points in question in the text (pp. 59, 60, 61 and 64; see footnote on p. 23). In this paper there is no interest for the examples of the head muscles of the types iii), vi) and vii) (see the pages 60, 65 and 65 no more than for all muscles lying entirely in the body outside the head, thus tail and extremities included.

(*a*) (*β*) Characters of shape and attachment of the muscles determining the course of the muscle fibres

(*β*) (1) The external shape of the muscle with regard to the composition of the muscle

In this respect we have to distinguish four types of muscles. They are:

i) The single, non-branched, non-forked muscle.

This is also called a compact muscle (BURGGRAAF & FUCHS, 1955, p. 98).

ii) The branched, forked muscle.

This is also called a ramified muscle (BURGGRAAF & FUCHS, 1955, p. 98).

Examples: (1) In the rostral part of the musculus rectus capitis lateralis in *Phasianus colchicus* L. and in *Perdix perdix* L. the many parallel muscle fibres constitute one flat muscle bundle at each side, which more caudalwards branches into three flat bundles, attached respectively to the 2nd, 3rd and 4th cervical vertebra (DEN BOER, 1953, pp. 455-456).

(2) In the musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. with the 3 branches of the medial part and the 5 branches of the lateral part we find that the 1st branch of the medial part is situated against the 3rd branch of the lateral part (they are clearly distinct), that the 2nd medial branch lies against the 4th lateral branch (they are difficult to separate) and that the 3rd medial branch lies against the 5th lateral branch (with which it is completely fused) (DEN BOER, 1953, pp. 457-458).

iii) The composite or combined muscle, interrupted by a piece of non-muscular tissue which separates two parts of one muscle or connects two or more muscles.

iv) The composite muscle, interrupted by a number of myosepta of non-muscular tissue which connect a number of segments of a muscle.

These myosepta may be called aponeuroses as they are flat membranes of connective tissue, which, through the muscle fibres attached to them, have a function in transferring tension (MANGER CATS, 1951, pp. 192, 300; DULLEMEIJER, 1956a, pp. 27-28, 29; 1956b, pp. 413-414, 415).

(*β*) (2) The external shape of the muscle and its branches with regard to the course of the axis of a simple muscle or of the branches of a muscle

This course can be:

i) straight; the single muscle shows a straight course or the branches of the muscle do so.

ii) curved; the single muscle shows a curved course or branches of a muscle do so.

Examples: (1) The right part A_1 of the musculus adductor mandibulae in *Pleuronectes platessa* L. runs more or less in a curve round the eye (DE BLOK, 1957, p. 89).

(2) The musculus $A_1m\beta$ in *Sphaeroides oblongus* (Bloch) has its caudo-dorsal surface curved like the eye; this thin part of the muscle runs below the eye (SARKAR, 1960, p. 88).

(3) The musculus mylohyoideus posterior in *Anas platyrhyncha platyrhyncha* (L.) runs from the musculous attachment on the lateral surface of the ascending point of the processus angularis posterior of the lower jaw shortly rostro-ventralwards, turns round the ventral border of the lower jaw and attaches on the corpus hyale (DAVIDS, 1952, p. 538).

(4) The end of the muscle fibres of the musculus serpihyoideus in *Phasianus colchicus* L. curves ventralwards round the processus retro-articularis (BURGGRAAF, 1954, pp. 675-676).

(5) The muscle fibres of the musculus stylohyoideus in *Phasianus colchicus* L. are curved, as they run over the ventral edge of the processus retro-articularis (BURGGRAAF, 1954, p. 676).

(6) The end of the muscle fibres of the musculus geniohyoideus in *Phasianus colchicus* L. is curved round the cornua of the hyoid arch in an indistinct spiral: seen from the rostral side the course of the spiral is ventral-medial-dorsal-lateral (BURGGRAAF, 1954, pp. 676/677).

(7) The musculus temporalis in *Ondatra zibethica* (L.) has a characteristic curved form: the muscle fibres run rostralwards, there they bend ventralwards and run caudally of the eye to the lower jaw (VAN VENDELOO, 1953, p. 265).

(β) (3) The structure of the muscle with regard to the topographical relation of the muscle fibres in their attachment to the skeleton whether or not through the medium of aponeuroses

DULLEMEIJER (1952, pp. 95-96, 102) distinguishes in this respect:

i) The simple muscle in which the muscle fibres run straight from one place of attachment to the other.

This form is seldom found. The muscle fibres may run parallel or they may cross each other. In my opinion the muscle fibres may also have a curved course or may diverge or converge.

ii) The composite muscle in which the muscle fibres do not run straight from one bone to the other, but are always attached to it by means of aponeuroses.

BURGGRAAF & FUCHS (1955, p. 98) call simple muscles those muscles that are attached to the bone directly without the intermediary of aponeuroses, but they call muscles that are attached by means of aponeuroses "complex" muscles. BURGGRAAF (1954, p. 303) uses the term "complex muscle" in this respect; thus the musculus adductor mandibulae externus in

Phasianus colchicus L. which contains many aponeuroses is called by him a "very complex muscle".

(β) (4) The way of attachment of the head muscles

With regard to the way of attachment of the head-muscles we have to distinguish an attachment to soft parts and an attachment to the skull. This latter attachment can be a direct attachment of the muscle fibres to the skull or an indirect one by means of one or two interlinked elements, consisting of firm and stout tissue (bone, cartilage, aponeurosis, tendon). Such firm and stout tissue is not found in the cases of an attachment to soft parts.

When an attachment of the muscle to the skull is found, then this attachment can be a direct or an indirect one.

To understand the different conditions found in these cases, we have to distinguish the different elements that can occur. We can distinguish at the utmost five different elements, to be called:

i) the general surface-form of the skull;

ii) the so-called carrying surface on the skull;

iii) the projections, deepenings and undulations of the surface of the skull, carried by the elements under ii);

iv) the aponeuroses or tendons for the attachment of muscle fibres;

v) the muscle fibres.

Independent of these, we have to distinguish the surfaces of direct attachment, of indirect attachment and the interlinked elements, the notions of which are dealt with below.

In a number of cases only there is no difference between the general surface-form of the skull, being the surrounding surface in that region of the skull, and the so-called carrying surface. Under certain circumstances only there is a direct connection between the shape of the general surface-form of the skull and that of the carrying surface. This does exist in the case that the skull as a whole displays a single surface-form. Then the carrying surfaces are taken up in the general surface-form of the skull.

The carrying surface is that part of the surface of the skull that carries either the projections, deepenings and undulations of the surface of the skull or the aponeuroses and tendines directly.

The carrying surface in these cases acts in other cases as a surface of direct attachment of muscle fibres in the case of a musculous attachment.

As a surface of direct attachment can act the carrying surface, the projections *etc.* and the aponeuroses *etc.*

We speak of interlinked elements in the case there occurs between the carrying surface and the muscle fibres one or two of the elements mentioned, thus projections *etc.* or (and) aponeuroses *etc.* only.

We may distinguish the following categories of cases.

α) In the cases there is no difference between the general surface-form of the skull and the carrying surface, this common surface may carry: a) muscle fibres; b) projections *etc.* and muscle fibres; c) aponeuroses *etc.* and muscle fibres; d) projections *etc.* and aponeuroses *etc.* and muscle fibres.

β) In the cases there does occur a difference between the general surface-form and the carrying surface, this latter surface may carry: e) muscle fibres; f) projections *etc.* and muscle fibres; g) aponeuroses *etc.* and muscle fibres; h) projections *etc.* and aponeuroses *etc.* and muscle fibres.

(3) (b) The mutual course of the muscle fibres and the angle between the muscle fibres and the surface of direct attachment

We have described as a standard that the muscle fibres run parallel or nearly parallel to each other. In this standard condition the angle between the muscle fibres and the skeletal carrying surface plays a role. In the cases we find an interlinked element (skeletal projection *etc.*, aponeurosis *etc.)*, the angle with the direct surface of attachment does not play a primary role.

Confining ourselves to start with to the first type of muscles (muscles with both attachments to the skull), we find with regard to the mutual course of the muscle fibres in the four types of muscles, mentioned above (p. 66), the following:

(b) i) The type of the single, non-branched, non-forked muscle

The appearance of such a muscle depends on that mutual course of the muscle fibres through which they are closely bound up with each other. This may occur even when the area of attachment at one or at both muscle-ends shows a combination of a number of places of attachment of a different character, such as a smooth flat surface, as a crista, as a spina, with or without internal aponeuroses or tendines. with or without external aponeuroses or funnels, *etc.*

Examples: (1) The muscle fibres of the musculus coraco-hyoideus in *Squalus acanthias* L. which run more or less parallel to the median plane, make an angle of about 45° with the slightly curved ventral-facing surface of the cartilage of the copula of the hyoid; those attached to the very narrow, no doubt plane, caudal-facing surface of the copula of the hyoid are almost perpendicular to it (Van den Assem, 1952, p. 661).

We will discuss here the course of the muscle fibres with regard to the surface of direct attachment and to the interlinked elements. The course of the muscle fibres with regard to their carrying surface will be discussed later.

In a single, non-branched, non-forked muscle the muscle fibres may run parallel or nearly parallel to each other, they may converge, they may diverge or they may run in different directions (a survey of a number of these types of muscles, based on the relative size of both places of musculous attachment of a muscle, is given by DEN BOER, 1953, pp. 470-472). They present themselves in the following conditions (plate 23).

i) a. A parallel course of the muscle fibres

The muscle fibres may run parallel to each other or nearly parallel. This may occur in the following cases.

a 1). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth flat surface of attachment. Then the angle of implanting is 90°, or smaller than 90° to very acute, which depends on the fact whether this surface of attachment is perpendicular to the central axis of the muscle, or makes a smaller angle of widely different size with it.

Examples: (1) The muscle fibres of the musculus coraco-arcualis II in *Squalus acanthias* L. attach with acute angles in a musculous way to hypobranchiale II (VAN DEN ASSEM, 1952, p. 666).

a 2). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth concave surface of attachment. In that case a parallel course of the muscle fibres occurs under certain circumstances only. Then the angle of implanting of the central muscle fibres on the tangent plane to this spot of the concavity is 90°, or smaller than 90° to very acute, which depends on the fact whether this tangent plane to the centre of the concave surface of attachment is perpendicular to the central axis of the muscle, or makes a smaller angle of widely different size with it. The non-central muscle fibres gradually alter this angle with the various layers of muscle fibres.

a 3). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth convex surface of attachment. In that case a parallel course of the muscle fibres occurs under certain circumstances only. Then the angle of implanting of the central muscle fibres on the tangent plane to this spot of the convexity is 90°, or smaller than 90° to very acute, which depends on the fact whether this tangent plane to the centre of the convex surface of attachment is perpendicular to the central axis of the muscle, or makes a smaller angle of widely different size with it. The non-central muscle fibres gradually alter this angle with the various layers of muscle fibres from the centre to the periphery.

a 4). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a rather broad surface of musculous attachment on both surfaces of a crest. In that case a parallel course of the muscle fibres occurs under certain circumstances only. Then the muscle fibres attached to each side of the crest and those of both sides as well, run parallel with each other. The number of muscle fibres occurring one on the other in proximal-distal direction, will have to be very small, since the distance between the muscle fibres in a surface perpendicular to their lengths has to exceed a certain minimum, by which the distance between the places of attachment will have to be fairly considerable.

a 5). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a rather large surface of musculous attachment on a spina. In that case a parallel course of the muscle fibres attached all-round the spina occurs under certain circumstances only. Then the muscle fibres run parallel with each other. For the above-mentioned reason the number of these muscle fibres will be very small.

a 6). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres are implanted on an internal aponeurosis. Then the angle of implanting of these tangentially attached muscle fibres is very acute. For the above-mentioned reason the number of these muscle fibres will be very small.

a 7). A parallel or nearly parallel course of the muscle fibres occurs in the case that the muscle fibres are implanted on an external aponeurosis. The angle of implanting of the tangentially attached muscle fibres is very acute. For the above-mentioned reason the number of these muscle fibres will be very small. The angle of implanting may also be larger under certain circumstances; this is only conceivable when the external plate-shaped aponeurosis is kept in its position in another way, *e.g.* owing to ossification of the basis of the complicated aponeurosis-system to which the external aponeurosis belongs (BURGGRAAF & FUCHS, 1954, p. 289; BURGGRAAF, 1954, pp. 299, 300, 303) (this ossification makes it possible that the angles of implantation are different on both surfaces), or through the external aponeurosis becoming an internal aponeurosis near its free margin.

i) b. A convergent course of the muscle fibres

The muscle fibres may converge. This is the case when the opposite surface of attachment is a smaller one. The muscle fibres may show a convergent course in the following cases:

b 1). A convergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth concave surface of attachment. Then the muscle fibres are implanted perpendicularly.

b 2). A convergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth flat surface of attachment. In that case a convergent course of the muscle fibres occurs under certain circumstances only. Then the angle of implanting of the central muscle fibres is 90°, or smaller than 90° to very acute. The non-central muscle fibres gradually alter this angle with the various layers of muscle fibres.

Examples: (1) The comparatively flat dorsal part of the extensive area of musculous attachment on the caudal wall of the skull of the fan-shaped musculus splenius capitis in *Phasianus colchicus* L. shows a converging bundle of muscle fibres running to the small place of attachment on the 2nd cervical vertebra; at this place of attachment so much connective tissue is found between the muscle fibres, that it may be justified to speak of an aponeurotic attachment (DEN BOER, 1953, pp. 336, 343, 471).

b 3). A convergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth convex surface of attachment. In that case a convergent course of the muscle fibres occurs under certain circumstances only. Then the angle of implanting of the central muscle fibres is 90°, or smaller than 90° to very acute. The non-central muscle fibres gradually alter this angle with the various layers of muscle fibres.

Examples: (1) The highly curved ventro-lateral part of the extensive area of musculous attachment on the caudal wall of the skull of the fan-shaped musculus splenius capitis in *Phasianus colchicus* L. shows a converging bundle of muscle fibres running to the small place of attachment on the 2nd cervical vertebra; at this place of attachment so much connective tissue is found between the muscle fibres, that it may be justified to speak of an aponeurotic attachment (DEN BOER, 1953, pp. 336, 343, 471). The total area of musculous attachment, the comparatively flat dorsal part as well as the highly curved ventro-lateral part, on the caudal wall of the skull, of the musculus splenius capitis is very extensive. In two skulls of *Phasianus colchicus* L. the total area of attachment of the musculus splenius capitis was calculated at 185.5 mm^2 and 204 mm^2 respectively, whereas the total surface of the caudal wall of the skull and the knob on the basisphenoid (this means the total area available for the attachment of the cervical muscles) amounted to 489.5 mm^2 and 510 mm^2 respectively, proving the relation of the area of attachment of the musculus splenius capitis to the total available area to be 0.379 respectively 0.40. For one skull of *Perdix perdix* L. these three figures are: 67.5 mm^2, 257.5 mm^2 and 0.262. The musculus splenius capitis in *Phasianus colchicus* L. is relatively more developed than in *Perdix perdix* L. (DEN BOER, 1953, pp. 344-345).

b 4). A convergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on both surfaces of a crest. In that case the muscle fibres may not be expected to converge, even if the surface for musculous attachment is broad. This may happen, however, in the planes parallel to that of the crest in the case of a long plate-like crest.

b 5). A convergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on the surface of a spina. In that case the muscle fibres may not be expected to converge, even if the surface for musculous attachment is relatively very large.

b 6). A convergent course of the muscle fibres occurs in the case that the muscle fibres are implanted on an internal aponeurosis. In that case the muscle fibres implanted on both surfaces may not be expected to converge. This may happen, however, in the planes parallel to that of the internal aponeurosis in the case of a long plate-like internal aponeurosis.

b 7). A convergent course of the muscle fibres occurs in the case that the muscle fibres are implanted on an external aponeurosis. In that case the muscle fibres may not be expected to converge, or to a small degree only. This may happen, however, in the planes parallel to that of the external aponeurosis in the case of a long plate-like external aponeurosis.

i) c. A divergent course of the muscle fibres

The muscle fibres may show a divergent course. This is the case when the opposite surface of attachment is a larger one. The muscle fibres may diverge in the following cases.

c 1). A divergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth convex surface of attachment. Then the muscle fibres are implanted perpendicularly.

Examples: (1) In the antagonist of the musculus dorsolateralis in *Raja batis* L. the most caudal muscle fibres that show a musculous attachment on the caudal surface of the skull, probably on the condylus lateralis, are directed at an angle of about 40° with the median; rostralwards this angle increases more and more and the most rostral fibres are at an angle of 90° (Gottenbos, 1956, p. 733).

(2) In the powerful medial part of the divergent musculus rectus capitis ventralis in *Phasianus colchicus* L. the angle of attachment to the knob of the basisphenoid changes from nearly 90° to practically 0°, thus from perpendicularly (the most caudally attached muscle fibres) to about tangentially (the most rostrally attached muscle fibres) (Den Boer, 1953, pp. 464, 468). In this also divergent muscle in *Perdix perdix* L. the angle of attachment to all points of the knob of the basisphenoid is about the same (Den Boer, 1953, pp. 467, 468). This is due to the fact that the shape of the surface of the place of attachment (the knob of the basisphenoid) is essentially different: in *Phasianus* this knob is markedly vaulted (it is nearly semicircular in section), in *Perdix* it is nearly entirely flat. So in *Perdix* the area of attachment of the medial part of the musculus rectus capitis ventralis will be relatively less extensive than in *Phasianus*. To express this fact quantitatively, the surface of the knob of the basisphenoid, the total area available for the attachment of cervical muscles to the skull, and the relation of the area of attachment of the musculus rectus capitis ventralis to the total area available for the attachment of cervical muscles were determined as exactly as possible. These figures are for one skull of *Phasianus colchicus* L. 160.5 mm^2, 489.5 mm^2 and 0.328, for another skull of *Phasianus* 173 mm^2, 510 mm^2 and 0.339, and for one skull of *Perdix perdix* L. 76 mm^2, 257.5 mm^2 and 0.296. So the place of attachment of the medial part of the musculus rectus capitis

ventralis indeed seems to be smaller in *Perdix* than in *Phasianus* (however, it is questionable whether this difference is real) (DEN BOER, 1953, p. 467). No doubt there is a relation between the function of the musculus rectus capitis ventralis and the development of the knob of the basisphenoid (DEN BOER, 1953, pp. 335, 336, 338).

c 2). A divergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth flat surface of attachment. In that case a divergent course of the muscle fibres occurs under certain conditions only. Then the angle of implanting of the central muscle fibres is 90°, or smaller than 90° to very acute. The non-central muscle fibres alter this angle with various layers of muscle fibres.

c 3). A divergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a smooth concave surface of attachment. In that case the muscle fibres may not be expected to diverge, or to a small degree only.

c 4). A divergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a rather broad surface of musculous attachment on both surfaces of a crest. In that case a divergent course of the muscle fibres occurs under certain circumstances only. Then the muscle fibres attached to each side of the crest form together one whole without a parting along the line of the edge of the crest. Then the muscle fibres diverge from each other on each side in such a way that the angle between the muscle fibre and the surface of the crest becomes larger in the distal-proximal direction.

c 5). A divergent course of the muscle fibres occurs in the case that the muscle fibres show a musculous attachment on a rather large surface of musculous attachment all round a spina. In that case a divergent course of the muscle fibres occurs under certain circumstances only. Then the muscle fibres form together one whole without a central cavity. Then the muscle fibres diverge from each other in such a way that the angle between the muscle fibre and the surface of the spina becomes larger in a distal-proximal direction. Highly divergent muscle fibres on a spina cannot very well be imagined, when there is no internal tendon attached to the spina.

c 6). A divergent course of the muscle fibres occurs in the case that the muscle fibres are implanted on an internal aponeurosis. In that case a divergent course of the muscle fibres occurs under certain circumstances only. Then the angle under which the muscle fibres are implanted becomes larger in distal-proximal direction, increasing from a very acute angle to an angle of 90°. If the muscle fibres on both surfaces contract simultaneously and to the same extent, we may expect the angle of attachment on the internal aponeurosis to be equal on one and the same height; it may, however, vary from a very acute angle to an angle of 90°.

If the muscle fibres on both surfaces do not contract simultaneously or as strongly, the angle of incidence may be different, but it will never greatly deviate from a nearly tangential attachment. With the internal tendon we find comparable conditions.

Examples: (1) In the antagonist of the musculus dorsolateralis in *Raja batis* L. the muscle fibres attached on the free top of the internal aponeurosis diverge in a fan-like way; those lying in the plane of the aponeurosis are directed at angles of 0°-20° to the axis of the aponeurosis; the angle of the muscle fibres, which run ventralwards and rostralwards, with a vertical plane increases from 25° to 50° in a rostral direction (GOTTENBOS, 1956, pp. 732, 733).

c 7). A divergent course of the muscle fibres occurs in the case that the muscle fibres are attached on an external aponeurosis. In that case a divergent course of the muscle fibres occurs under certain circumstances only. Then the angle under which the muscle fibres are implanted becomes larger in a distal-proximal direction, the muscle fibres may not be expected to diverge, or to a small degree only. In the planes parallel to that of the external aponeurosis the muscle fibres may diverge, resulting in a fan-shaped thin muscle.

Examples: (1) The musculus depressor hyomandibularis in *Raja batis* L. is implanted on a dorsal external aponeurosis which is attached to the ventral surface of the narrow rostral part of the hyomandibulare which is somewhat thickened all round and is shaped like a small knob (GOTTENBOS, 1956, pp. 551-553, 734).

i) d. The muscle fibres may form interrupted zigzag lines

The interruption is caused by internal aponeuroses. This type of muscle may occur in the case that the one single muscle consists of a system of a number of feather-shaped units lying in juxtaposition parallel to each other. In these muscles the internal aponeuroses are attached to the two opposite surfaces of attachment forming a system of side-scenes and showing an alternation of the aponeuroses. These muscles may be attached to internal aponeuroses and partly to the skull; at the periphery of the muscle we may find external aponeuroses (see DULLEMEIJER, 1952, p. 96).

i) e. The muscle fibres may cross each other

This may occur in the case that the one single muscle consists of various layers in which the muscle fibres do not run parallel or do not show a convergent or a divergent course, but show quite different courses. These layers of muscle fibres may be attached to different kinds of surfaces of attachment.

Examples: (1) In the antagonist of the musculus dorsolateralis of *Raja batis* L. the muscle fibres coming from the most rostral part of the connective tissue sheet on the lateral surface of the musculus dorsolateralis run with a slight curve over the other fibres along the rod γ (read α); the muscle fibres which show the most dorsal attachment to the lateral part of the aponeurosis, which is curved dorsally, curve round the other muscle fibres (GOTTENBOS, 1956, pp. 732, 733).

(b) ii) The type of the branched, forked muscle

The appearance of such a muscle depends on that course of the muscle fibres through which they run in diverging muscle bundles, thus giving rise to a branched or forked muscle. This occurs in the case that all the muscle fibres of the muscle mentioned have a common basal part, but diverging distal parts. The latter is due to the diverging course of two or more bundles of muscle fibres. These diverging bundles have one common, united, joined basal part, attached to a smooth flat, concave or convex surface, to a crest or to an aponeurosis.

Examples: (1) The musculus complexus in *Phasianus colchicus* L. consists of a rather thick rostral bundle which at the height of the 2nd cervical vertebra branches into two thin and flat bundles in the cervical region (DEN BOER, 1953, p. 339).

(2) The musculus rectus capitis lateralis in *Phasianus colchicus* L. and in *Perdix perdix* L. consists of a rather broad rostral bundle, which soon branches into three thin bundles in the cervical region (DEN BOER, 1953, pp. 455-456).

(3) The medial part of the musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull in 3 branches to the 3rd, 4th and 5th cervical vertebra (DEN BOER, 1953, pp. 456-457).

(4) The lateral part of the musculus rectus capitis superior in *Phasianus colchicus* L. and in *Perdix perdix* L. runs from the caudal wall of the skull in 5 branches to the 1st up to and including the 5th cervical vertebra (DEN BOER, 1953, p. 457).

(5) The powerful medial part of the musculus rectus capitis ventralis in *Phasianus colchicus* L. runs from the knob on the basisphenoid in 4 branches to the 1st up to and including the 4th cervical vertebra (DEN BOER, 1953, p. 459). In *Perdix perdix* L. this medial part shows 5 branches respectively attached to the 1st up to and including the 5th cervical vertebra (DEN BOER, 1953, p. 465).

(6) The smaller lateral part of the musculus rectus capitis ventralis in *Phasianus colchicus* L. runs from the tendon attached to the knob on the basisphenoid as a whole and more caudally divides in 2 branches to the 5th and 6th cervical vertebra (DEN BOER, 1953, p. 460). In *Perdix perdix* L. this lateral part, which is far less developed than in *Phasianus* consists of only one branch attached to the 6th cervical vertebra (DEN BOER, 1953, p. 466).

(7) The musculus adductor mandibulae externus, the musculus adductor mandibulae posterior, the small muscle bundle connecting these two, and the musculus adductor mandibulae internus pseudotemporalis profundus in *Phasianus colchicus* L. are not entirely separated from each other, but are connected in such a way that the demarcation between the places of attachment of the muscle fibres is not sharp. For these and other reasons the complex of the muscles mentioned might be considered as one morphologically continuous unity (FUCHS, 1954, pp. 458-459, 461).

In the opinion of LAKJER (1926, p. 44), however, the more complex muscles consist of muscle portions, which show limiting surfaces covered by aponeuroses; these aponeuroses have no greater function. This agrees with LAKJER's opinion (1926, pp. 29-31) on the stages of development of the aponeuroses. According to this author a number of groups of fibres are transformed into aponeuroses in the 1st stage of development; in the case this transformation is slightly developed it is found on one end of such a group of muscle fibres. In the 2nd stage the muscle fibres of one group, which originally are separated from neighbouring groups of parallel muscle fibres by such aponeuroses, are not separated any more from neighbouring groups of parallel muscle fibres by such aponeuroses, but are attached on the surface of these aponeuroses. In the 3rd stage one of the free margins of a plate-like aponeurosis shows a bent margin, causing a curved or bent aponeurosis, giving attachment to different portions of muscle fibres running in different directions. Thus in the 2nd stage aponeuroses separate bundles of muscle fibres, or in other words such aponeuroses divide all the groups of muscle fibres into a number of portions.

In the case of a common crest or a common internal aponeurosis, the muscle fibres attached to the two surfaces do not run parallel with each other, but diverge, owing to the fact that the muscle fibres are not implanted tangentially, but to a larger angle of implanting.

In such cases the crest or the internal aponeurosis might be called a separating crest or a separating internal aponeurosis, but in our opinion this term is not adequate, as such a crest or aponeurosis is a connecting crest and a connecting internal aponeurosis. — A crest can be a true separating crest as well, in the case that the right and left half of a paired muscle, or in the case that two different muscles are attached to it.

(b) iii) The type of the composite or combined muscle, interrupted by a piece of non-muscular tissue which separates two parts of one muscle or connects two or more muscles

The separating or the connecting piece of non-muscular tissue is a tendon or a simple aponeurosis or a complicated aponeurotic frame.

Three different cases can be distinguished.

In the first case, that of a tendon, the muscle fibres may run in muscle bundles with a parallel course, lying one behind the other, one being a lengthening-piece of the other, the angle between the two being 180°.

Examples: (1) The musculus biventer cervicis in *Phalacrocorax carbo sinensis* (Shaw & Nodder) is a long muscle with a very long and thin tendon, separating or connecting two muscle bundles with a parallel course, as described above (DULLEMEIJER, 1951, pp. 533/534).

(2) The musculus biventer cervicis in *Anas platyrhyncha platyrhyncha* (L.) is a long muscle with a long tendon separating or connecting two muscle bundles with the shape of a rostral and a caudal belly (DAVIDS, 1952, p. 535).

(3) The musculus biventer cervicis in *Phasianus colchicus* L. and in *Perdix perdix* L. is a long muscle with a long tendon, separating or connecting a weakly developed rostral and a much more developed caudal "venter", being two muscle bundles with a parallel course; the tendon lies dorsally of the rostral cervical vertebrae (DEN BOER, 1953, pp. 341-343).

In the second case, that of a simple aponeurosis, the muscle fibres may run in muscle bundles with a different course, the angle between the bundles being less than 180°.

In the third case, that of a complicated aponeurotic frame, we find muscles or muscle bundles with a different course, attached to a V-shaped gutter, showing an unpaired keel of solid connective tissue in the dorsal direction and bearing on this keel and on the gutter-shaped wings a caudo-laterally running band which shows connections with other aponeuroses and fascia (VAN DEN ASSEM, 1952, pp. 657, 662-664).

(b) iv) The type of the composite muscle, interrupted by a number of myosepta of non-muscular tissue which connect a number of segments of a muscle

As we have seen already (p. 66) these myosepta may be called aponeuroses as they are flat membranes of connective tissue, which, through the muscle fibres attached to them, have a function in transferring tension. In the cases that the muscles show a segmentation these myosepta or inscriptiones tendineae connect the segments of these muscles. The segments are of a flat, simple nature or they are curved (VAN DEN ASSEM, 1952, p. 658).

Examples: (1) In *Squalus acanthias* L. the musculus coracoideus is divided into sections by 3 or 4 inscriptiones tendineae which are flat (VAN DEN ASSEM, 1952, pp. 658, 673).

(2) In the Squaliformes, where the segments of the musculus dorsolateralis are curved, the aponeuroses are undulating in both directions, longitudinally as well as transversely; these flat ribbons are visible on the surface and in a longitudinal section as zigzag lines (MANGER CATS, 1951, p. 192).

We may expect the muscle fibres to run in muscle bundles with a parallel course, lying one behind the other, one being a lengthening-piece of the other, the angle between the two being 180°. Also in the Squaliformes with their curved segments we find the same. Between the places where the aponeuroses are bent, the muscle fibres diverge somewhat from the longitudinal direction of the muscle, the divergence never amounting to more than 10° (MANGER CATS, 1951, pp. 196/197). With regard to the surfaces of direct attachment on the skull surface the angle of implanting of the muscle fibres of the musculus dorsolateralis in Squaliformes is obtuse. The muscle fibres implanted on the internal aponeuroses, at least on the aponeuroses found in the most rostral part of the muscle, make an acute angle and at the curving point of the aponeurosis the implanting is practically perpendicular (MANGER CATS, 1951, pp. 198, 199).

The shape of a muscle depends to a large extent on the features just mentioned, such as the mutual course of the muscle fibres, parallel, convergent, divergent, feather-shaped in juxtaposition, crossing each other, the attachment to the surface of the skull or to a crest or to a spina or to an aponeurosis or to a tendon, *etc.*

(3) (c) The angle between the muscle fibres and the skeletal carrying surface

In the preceding paragraph we made some remarks on the angle between the muscle fibres and the surface of direct attachment, what indeed it was, skeletal carrying surface, projection *etc.*, aponeurosis *etc.*

In this paragraph the angle between the muscle fibres and the skeletal carrying surface asks our attention. In those cases in which the surface of direct attachment does not coincide with the skeletal carrying surface, we have new and additional questions to deal with in this paragraph.

We will confine ourselves here as well to the first type of muscles, mentioned on p. 57, *i.e.* those with both attachments to the skull and we will confine ourselves to the single, non-branched, non-forked muscle.

In the first place we can determine the angle between the muscle fibres, *i.e.* between the longitudinal axis of the muscle, and the skeletal carrying surface, expressed by means of the perpendicular on that surface.

In the second place we can determine the angles between the muscle fibres, the aponeurosis or tendon, the projection, deepening and undulation of the surface of the skull and the skeletal carrying surface. These angles can be determined between the longitudinal axis of the muscle, the plane of the aponeurosis, the axis of the tendon, the perpendicular axis on the smooth, flat, concave or convex surface, the perpendicular axis in the sinkings, acting as surfaces of attachment, the axis of the crista or the spina or of other protuberances and on the perpendicular on the skeletal carrying surface. Thus the angles along this broken or cracked line are determined, the number of angles depending on the number of interlinked elements. There can be none, one or two interlinked elements. One of them will be the surface of direct attachment, already treated in the preceding paragraph.

This second way of treatment gives rise to a number of remarks and questions.

The first question is that of the shape of the broken or cracked line in relation to the space available in the part of the head occupied by the muscle. Related to that is the question about the mutual position of the different surfaces for direct or indirect attachment and the mutual position in relation to the space available in that part of the head.

The second question is that about general rules concerning the relation between the position of the muscle fibres and that of the skeletal carrying surface. Such general rules cannot be given and even no general remarks can be made.

The third question is that about the position of the various individual interlinked elements *etc.* We find that the position of a crista, of a spina, *etc.*, of an internal aponeurosis or tendon and of an external aponeurosis or tendon, is to a higher degree independent on the position of the carrying surface than the position of a smooth, flat, concave or convex surface, is, at all events if such a surface shows a rather large extension. On the other hand, the position of a crista, of a spina *etc.*, of an internal aponeurosis and of an external aponeurosis is in many cases obviously connected to the coinciding course of the axis of the muscle or to that of the muscle fibres.

An additional remark can be made on the functional significance of the position of the elements mentioned.

Examples: (1) A part of the muscle fibres of the musculus dorsolateralis in Squaliformes shows a musculous attachment in the form of a strong attachment to the skeletal covering of the caudo-lateral surface of the canalis semicircularis anterior by means of connective tissue; these muscle fibres run tangentially to the carrying surface; if this covering of the canalis semicircularis had not been present a great tension would be exercised on the perichondrium, and the possibility of a severance between cartilage and perichondrium would be imminent because of the tension along the perichondrium (Manger Cats, 1951, p. 299).

(iii) (4) Parallel or non-parallel position of the surfaces carrying the places of attachment of the muscles

With regard to the position of the surfaces carrying the places of attachment of the muscles, we took as a standard the position in which the surfaces referred to run parallel to each other.

In nature we find as a deviation from this standard the condition that the two carrying surfaces do not run parallel to each other, but make an angle with each other. As we have already stated above, the position of the carrying surface is to a high degree independent on the course of the muscle fibres and thus also on the axis of the muscle in case that the surface of attachment is a protuberant element on the surface of the skull or is an aponeurosis. We have also stated above that this independence occurs to a lesser degree in the case of a more extensive smooth flat, concave or convex surface in the service of musculous attachment. In the chapter on the topographic-anatomical relations the relative positions of the carrying surfaces on both ends of a single muscle in regard to each other will be discussed in detail. Attention will also be given to the changes in the parallel or non-parallel condition of the carrying surfaces in relation to the degree of contraction of the muscle.

(iii) (5) Opposite or non-opposite position of the surfaces carrying the places of attachment of the muscles

With regard to the relative position of the surfaces carrying the places of attachment of the muscles, we accepted as a standard that the surfaces referred to are directly opposite each other, so that the connecting line of the centres of the two carrying surfaces makes a perpendicular line on the two carrying surfaces.

In nature we find as a deviation from this standard also the condition that this connecting line is not a perpendicular line on the two carrying surfaces, but makes an acute angle with these surfaces. In the chapter on the topographic-anatomical relations this point will also be discussed.

(iii) (6) Theoretically conceivable combinations; theoretically possible conditions; conditions realized in nature

(6) (a) Introduction

In the preceding paragraphs we have indicated the possible deviations from the conditions that we settled as a standard, on the five said points which play a part in the field of the ways of attachment of muscles to the skull with its surface and its projections, deepenings and undulations.

They are at the same time the possible deviations from the 243 theoretically conceivable combinations of muscle-attachment to the surface of the skull.

We might ask ourselves again, which of all these variations on the 243 theoretically conceivable combinations are known from nature. As we indicated before, such an enumeration, considering the stage of the examination, does not seem so important. However, it does seem of importance to examine which of all theoretically conceivable combinations with their many variations might now also belong to the theoretically possible conditions. This may lead to an understanding of the actually worked up conditions in which, after many investigations, we may expect a reliable survey in the future. Our knowledge of functional anatomy, of ecological morphology and of architectural or structural morphology of this field of skull-structure and muscle-attachment and their mutual relation, can give us nowadays already some insight and in the long run more and more insight in what must be considered impossible or improbable under all theoretically conceivable combinations. This knowledge in these three fields can also give us an insight in what must be reckoned among the theoretically possible conditions out of all theoretically conceivable combinations. And moreover, this knowledge can also give us an insight, where these theoretically possible conditions may be expected, considering function, ecological surroundings and architectural or structural scheme. Finally, this knowledge may give us an explanation of the so divergent conditions realized in nature.

(6) (b) Survey of the conditions realized in nature

We may end this chapter on the descriptive-anatomical examination with a survey of the conditions realized in nature, giving a number of examples in which the relation of the projections, deepenings and undulations of the surface of the skull to the attachment of muscles has been described. We will restrict our examples here to the following categories:

a) examples described in papers based on investigations made in the Zoological Laboratory of the University at Leiden; as a rule on published investigations only; in these investigations attention is paid to the points we are interested in here. This is not the case in the numerous cases of notes on the attachment of muscles to the skull. These notes taken from literature only mention the large morphological region of the skull or the morphological element of the skull, on which the spot or the area of attachment is found and give rough indications on the size and the general two-dimensional shape and size of this spot or area, but they do not describe the character of their surface, nor their way of attachment, nor their inclination, *etc.* (see VAN DER KLAAUW, 1952, pp. 375-464).

b) examples of muscles, lying entirely within the head and attached at both ends to the skull, either partly or entirely; examples of other muscles which are attached to skeletal elements outside the head or to soft parts in the head and in the body outside the head are for a large part incorporated in the preceding pages (see footnote on p. 23).

c) examples of those muscles of which two or more of the five points concerning the general conditions which occur and which are conceivable have been studied, *i.e.* with respect to:

1) the way of attachment of the muscles to the skull;

2) the forms of the projections, deepenings and undulations of the surface of the skull;

3) the course of the muscle fibres;

4) the parallel or non-parallel position of the surfaces carrying the places of attachment of muscles;

5) the opposite or non-opposite position of the surfaces carrying the places of attachment of the muscles.

We will group the examples under the headings I - XXVIII of the theoretically conceivable combinations of the forms of muscle-attachment at both muscle-ends (see p. 22 and plates 1 - 16).

Examples in which only facts about one or even sometimes about two of these five points are published, are as a rule incorporated in the preceding pages (see footnote on p. 23).

Heading I: musculous — musculous

(H I) i. *Scylliorhinus caniculus* L., *Mustelus mustelus* L. and *Squalus acanthias* L. (all Squaliformes; Pisces)

a. Musculus constrictor superficialis hyomandibularis

(MANGER CATS, 1951, pp. 196, 201, 296/297, 300)

This muscle runs a) from the regio otica of the neurocranium, b) to the hyomandibulare. The muscle is very thin.

1a. Musculous attachment. This occurs to the regio otica.

1b. Musculous attachment. This occurs to the hyomandibulare.

2a. Surface of the area of attachment. In *Scylliorhinus* this is a small strip of a larger shallow depression to the dorsal part of the lateral side of the regio otica. In *Squalus* this area fits in a shorter but higher quadrangular shallow concavity; the attachment does not take place along the very acute ending of the dorsal cartilaginous protruding margin with its sharp edge. In *Mustelus* the place of attachment is a strip-like part of the depression on the dorsal surface of the regio otica.

2b. Surface of the area of attachment. This is found to the dorsal surface of the hyomandibulare in *Mustelus* and in *Scylliorhinus*; it is a smooth surface faintly curved rostro-caudally. In *Squalus* the plane of attachment occupies a large part of the concave dorsal surface of the hyomandibulare.

3. Mutual course of the muscle fibres. This is no doubt parallel.

b. Musculus levator hyomandibularis

(MANGER CATS, 1951, pp. 297, 300)

It runs a) from the lateral side of the regia otica, b) to the extreme dorsal end of the hyomandibulare. This small and thin muscle is found as a separate muscle among the three investigated Squaliformes, in *Mustelus* only.

1a. Musculous attachment. This occurs to the regio otica.

1b. Musculous attachment. This occurs to the hyomandibulare.

3. Mutual course of the muscle fibres. This is no doubt parallel.

c. Musculus levator palatoquadrati

(MANGER CATS, 1951, pp. 201, 297, 299, 300)

This muscle runs a) from the regio otica, just caudally of the processus postorbitalis, on the dorsal part of the lateral surface of the regio otica, which area extends caudalwards as far as the area of attachment of other muscles, b) to the palatoquadratum.

1a. Musculous attachment. This occurs to the regio otica.

1b. Musculous attachment. This occurs to the palatoquadratum.

2a. Surface of the area of attachment. On the regio otica it forms a curved surface; in *Squalus* it has the form of a depression.

2b. Surface of the area of attachment. On the palatoquadratum it has the form of a strip.

3. Mutual course of the muscle fibres. Angle of these muscle fibres to the curved surface 90°-50°.

d. Musculi interbranchiales

(VAN DEN ASSEM, 1952, pp. 670/671)

These thin muscles in *Squalus acanthias* L. run a) from the ceratobranchialia of the internal branchial arches, b) to the extrabranchialia.

1a. Musculous attachment. This occurs to the ceratobranchialia.

1b. Musculous attachment. This occurs to the extrabranchialia.

2a. Surface of the area of attachment. No details are given on this area on the ceratobranchialia.

2b. Surface of the area of attachment. On the extrabanchialia it is partly an enlarged flat part, partly a narrower part.

3. Mutual course of the muscle fibres. Angles of the muscle fibres to both areas of attachment acute.

(H I) ii. *Raja batis* L. (Rajiformes; Pisces)

a. Musculus levator hyomandibularis

(GOTTENBOS, 1956, pp. 550-551)

This muscle runs a) from the dorsal and lateral walls of the regio otica, b) to a part of the dorsal surface of the hyomandibulare.

1a. Musculous attachment. It occurs to the regio otica.

1b. Musculous attachment. It occurs to the hyomandibulare.

2a. Surface of the area of attachment. On the regio otica it is convex, containing the rounded edge between the dorsal and lateral walls of the skull and the lateral surface of the entire rod α; it is bordered by the processus postorbitalis and the rounded ridge of the canalis semicircularis posterior and the groove γ.

2b. Surface of the area of attachment. On the hyomandibulare it is partly convex (parts of the dorsal surface of the hyomandibulare, the rounded dorsal surface of crista (2); no muscle fibres are attached to the rostro-medial and the caudo-lateral rounded edge of the hyomandibulare and of crista (2), partly concave (the rostral, the caudal and the medial surface of crista (2).

3. Mutual course of the muscle fibres. In the rostral part they run slightly curved lateralwards. The muscle fibres in the rostral part run lateralwards at an angle of 90° with the median. Those of the caudal parts run at an angle of 40° rostro-lateralwards. Those of the intermediate part of the muscle are at an angle with the median which gradually decreases from 90° to 40°. The size of the angle the muscle fibres make with the median plane are thus given, but not that which the muscle fibres make with the surface of both areas of attachment. The possible influence of the fact that the area of attachment on the regio otica slopes somewhat ventralwards in a caudal direction to the foramen occipitale, as well as in a lateral direction, on the position of the muscle fibres in relation to the surface of the area of attachment, is not discussed.

b. Musculus spiracularis

(GOTTENBOS, 1956, p. 553)

This muscle runs a) from the lateral wall of the regio otica, b) to the dorsal surface of the hyomandibulare. It curves round the spiraculum; in repose its accurate form is maintained by the spiracular cartilage. This muscle is long, narrow, band-like.

1a. Musculous attachment. This occurs to the regio otica.

1b. Musculous attachment. This occurs to the hyomandibulare.

2a. Surface of the area of attachment. It lies in the groove γ, *viz.* to the border between the broad and deep rostral half and the narrow shallow caudal part and to a part of the rostral half of the groove on the regio otica.

2b. Surface of the area of attachment. This area on the dorsal surface of the hyomandibulare, *viz.* to the medial side of the knob, is convex.

3. Mutual course of the muscle fibres. These muscle fibres are curved.

(H I) iii. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor arcus palatini

(Sarkar, 1960, pp. 44-45)

This muscle runs in a dorsal-ventral direction a) from the entire lateral border of the parasphenoid and its lateral process, b) to the dorsal margin of the entire palatoquadrate bar, the caudal border of the metapterygoid and the anterior shaft of the hyomandibula. The muscle is broad, thin and rectangular. Rostrally, the muscles of both sides are fused, ahead of the rostral part of the parasphenoid. This fused area is triangular; it is broad anteriorly and narrowed posteriorly towards the anterior part of the parasphenoid.

1a. Musculous attachment. This occurs to the lateral border of the parasphenoid and its lateral process.

1b. Musculous attachment. This occurs rostrally to the medial side of the palatine at an acute angle, to a rough surface near the dorsal border of the palatinum and to the caudal border of the metapterygoid and the anterior surface of the hyomandibular shaft.

2a. Surface of the area of attachment. This is a long, narrow rectangle with a small caudal broadening on the lateral process. The long sides of the rectangle are formed by the ventral edge of the parasphenoid and a low crista lying parallel to the edge of the parasphenoid and only a few mm from it. The small broader part is a more or less triangular area whose sides are formed by the ventral edge of the parasphenoid, a latero-caudal continuation of the crista and a medial-laterally directed, small crista on the lateral process.

2b. Surface of the area of attachment. The rough surface near the dorsal border of the palatine is somewhat triangular. There are no noticeable demarcation structures. The angles of attachment of the muscle fibres on the two bony parts, the caudal border of the metapterygoid and the anterior surface of the hyomandibular shaft, vary from 45° to 90°. This area of attachment is long and narrow, similar to the dorsal attachment.

b. Musculus hyohyoideus dorsalis

(Sarkar, 1960, pp. 58-59)

This broad but thin muscle runs a) from the ventral surface of the crista hyomandibularis near its articulation with the operculum, from the entire inner rostral surface of the praeoperculum and from the membranous connective tissue on the posterior dorsal surface of the last gill, b) towards the posterior surface of the crista of the wing-like expansion in the region of the branchiostegal rays and to two other areas outside the skull, that is to the ventral half of the antero-lateral surface of the cleithrum and to the medial surface of the caudo-dorsal projection of the cleithrum. — This muscle starts in a ventral direction and then turns dorso-medially. — The muscle is situated medial to the praeoperculum and lateral to the gills.

1a. Musculous attachment. This occurs to the ventral surface of the crista hyomandibularis near its articulation with the operculum; this area of attachment is short, restricted to the area bounded by the dorsal end of the praeoperculum and the articulating region of the operculum. This posterior part of the muscle is the longer one.

This musculous attachment occurs also to the entire inner rostral surface of the praeoperculum (where the praeoperculum is connected to the hyomandibular shaft, symplecticum and metapterygoid). On this inner rostral surface of the praeoperculum, which is ventral to the dorsal continuation of the costa (1) the area of attachment is long. This anterior part of the muscle is the shorter one.

1b. Musculous attachment. This occurs to the posterior surface of the posterior rim of the crista (7) of the wing-like expansion; this area of attachment is narrow and slightly curved.

3. Mutual course of the muscle fibres. As only a part of the muscle fibres are attached to an element of the skull, it is of no value to discuss the mutual course of the muscle fibres.

(H I) iv. *Rana esculenta* L. (Salientia; Amphibia)

a. Musculus adductor mandibulae posterior subexternus

(Cool, 1953, p. 232)

This muscle runs a) from the processus zygomaticus of the squamosum and from the handle of the squamosum, b) to the Meckel's cartilage of the lower jaw.

1a. Musculous attachment. This occurs to the processus zygomaticus and the handle of the squamosum.

1b. Musculous attachment. This occurs to the lower jaw.

2a. Surface of the area of attachment. This area on the medial surface of the processus zygomaticus of the squamosum consists of a slight excavation over a short distance only. This area on the medial surface of the handle of the squamosum is in my opinion probably a plane surface in some specimens; in other specimens the place of attachment only occupies the rostral border of the handle of the squamosum.

2b. Surface of the area of attachment. This area on the lateral surface of the convex Meckel's cartilage is a narrow place.

b. Musculus adductor mandibulae posterior lateralis

(Cool, 1953, pp. 232-236)

This muscle runs a) from the caudal end of the quadratomaxillare and adjacent elements, b) to the lower jaw.

1a. Musculous attachment. This occurs to the caudal end of the quadratomaxillare.

1b. Musculous attachment. This occurs to the lower jaw.

2a. Surface of the area of attachment. This area on the caudal end of the quadratomaxillare consists for the greater part in an in my opinion convex area on the rostral surface of the disk-shaped caudal end of the quadratomaxillare; this area of attachment is bordered medially by a crista on the quadratomaxillare and for a lesser part on the medial surface of the handle of the squamosum which in my opinion is a plane surface, reaching as far as the longitudinal crista-like edge, situated rostro-laterally. In a number of specimens the area of attachment lies also on the lateral leg of the pterygoid and on the quadratum; the shape of this area of attachment may be rather varying in different specimens.

2b. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This area on the lateral surface of the lower jaw, mainly on the goniale, consists of an in my opinion probably plane surface and often for a very small part also of the convex Meckel's cartilage.

c. Musculus adductor mandibulae posterior articularis

(Cool, 1953, pp. 239-241)

This muscle runs a) from the medial surface of the handle of the squamosum and from the quadratum, b) to the lower jaw, partly to the processus coronoideus which probably has a vertical position.

1a. M u s c u l o u s a t t a c h m e n t. This occurs to the handle of the squamosum and to the quadratum.

1b. M u s c u l o u s a t t a c h m e n t. This occurs to the lower jaw.

2a. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This consists for the greater part of an in my opinion probably plane medial surface of the handle of the squamosum, the border running along a crista-like ridge on the surface of this handle, and for a small part of an in my opinion probably plane surface of the cartilaginous quadratum.

2b. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This consists for the greater part of an area on the lateral surface of the in my opinion probably plane osseous processus coronoideus and for a small part of the convex Meckel's cartilage.

(H I) v. *Vipera berus* (L.) (Serpentes; Reptilia)

a. Musculus adductor mandibulae externus profundus

(Dullemeijer, 1956a, pp. 16-17; 1956b, pp. 402-403)

This muscle runs a) from the quadratum, b) to the caudal part of the lower jaw and to the glandula venenata. The rostral part of the muscle is divided into a lateral and a medial part; the caudal end of the muscle is undivided.

1a. M u s c u l o u s a t t a c h m e n t. This occurs to the quadratum.

1b. M u s c u l o u s a t t a c h m e n t. This occurs to the caudal part of the lower jaw.

2a. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This area to the quadratum is very probably rounded; the dorsal and ventral borders are rather variable, but they never cover the cartilage surrounding the quadratum.

2b. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This area to the lower jaw lies on the rounded lateral surface of the lower jaw itself, on the wall of the groove-like canalis primordialis and a little to the dorsal plate-shaped extension and to the dorsal ridge of this extension on the lower jaw.

3. M u t u a l c o u r s e o f t h e m u s c l e f i b r e s. The angle of these fibres with the quadratum at the place of implanting is almost 90°. This angle of 90° lies in the plane of the flattened quadratum perpendicularly to the longitudinal axis of the quadratum (1956a, pp. 17, 86; 1956b, pp. 403, 472; personal communication). The muscle fibres run in such a way that the rostral part of the muscle is divided into two parts.

b. Musculus adductor mandibulae posterior

(Dullemeijer, 1956a, p. 18; 1956b, p. 404)

This muscle runs a) from the quadratum, b) to the medial plane of the plate-shaped extension of the lower jaw.

1a. Musculous attachment. This occurs to the quadratum.

1b. Musculous attachment. This occurs to the mentioned plane of the lower jaw.

2a. Surface of the area of attachment. This area on the quadratum is very narrow; it is very probably rounded.

2b. Surface of the area of attachment. This area on the above-mentioned extension is very probably plane.

3. Mutual course of the muscle fibres. These fibres reach the lower jaw dorsally with a sharp angle, so that the fibres are attached to the bone at relatively great distances from each other. The muscle fibres run in the plane of the flattened surface of the quadratum parallel to the longitudinal axis of the quadratum (1956a, p. 86; 1956b, p. 472; personal communication).

c. Musculus levator pterygoidei

(Dullemeijer, 1956a, p. 22; 1956b, p. 408)

This muscle runs a) from the cerebral skull caudal to the orbita, just ventro-caudal to and under the base of the processus postorbitalis, b) to the dorsal plane of the pterygoid, around and caudal to the articulation with the transversum. The rostral muscle fibres are shorter than the caudal ones.

1a. Musculous attachment. This occurs to the cerebral skull.

1b. Musculous attachment. This occurs to the pterygoid.

2a. Surface of the area of attachment. This area to the cerebral skull is not sharply demarcated but very probably rounded.

2b. Surface of the area of attachment. This area to the pterygoid lies in the medial groove, lying between the medial part of the pterygoid (in a transverse section this is wave-shaped) and the lateral part; this medial groove is facing dorsalwards.

3. Mutual course of the muscle fibres. The angles of the musculously attached muscle fibres are very sharp; in the lateral part of the area of attachment they only glide over the skull and are connected to it by loose connective tissue.

d. Musculus protractor pterygoidei

(Dullemeijer, 1956a, pp. 22-23; 106; 1956b, pp. 408-409, 492)

This muscle runs a) from the ventral surface of the cerebral skull, caudal to the orbita, b) to the dorsal plane of the caudal part of the pterygoid.

1a. Musculous attachment. This occurs to the cerebral skull.

1b. Musculous attachment. This occurs to the pterygoid.

2a. Surface of the area of attachment. This area to the cerebral skull is a shallow fossa with an almost triangular shape; this area lies between the crista on the latero-ventral surface of the parasphenoid and the costa on the ventral surface of the parasphenoid, running from the lateral angle in a medio-caudal direction and in its caudal part in a caudal direction in the median line. This medial part of the costa separates right and left area of attachment.

2b. Surface of the area of attachment. This area to the pterygoid lies in the medial groove, lying between the medial part of the pterygoid (in a transverse section this is wave-shaped) and the lateral part; this medial groove is facing dorsalwards.

3. Mutual course of the muscle fibres. They run parallel from one place of attachment to the other.

e. Musculus retractor palatini

(Dullemeijer, 1956a, p. 24; 1956b, p. 410)

This muscle runs a) from the ventral surface of the cerebral skull, caudal to the orbita, b) to the palatinum and in some cases also to the pterygoid.

1a. Musculous attachment. This occurs to the cerebral skull.

1b. Musculous attachment. This occurs to the caudo-dorsal side of the palatinum; in some cases it extends a short distance on both sides of the palatinum and on the rostro-dorsal side of the pterygoid.

2a. Surface of the area of attachment. This lies in an undeep continuation of a groove; the area is narrow, rather short and not clearly outlined.

2b. Surface of the area of attachment. This area is narrow, but in some cases it is extended.

3. Mutual course of the muscle fibres. They run parallel.

f. Musculus intermandibularis posterior

(Dullemeijer, 1956a, p. 30; 1956b, p. 416)

This muscle runs a) from the lower jaw, b) to the tongue and the median plane.

1a. Musculous attachment. This occurs to a small oval spot without sharp demarcations about halfway the length on the medio-ventral surface of the lower jaw.

1b. Musculous attachment. This occurs to a connective tissue plate, forming a sheath round the tongue and connected with the tongue-bone. In some cases the fibres of the muscles from both sides meet each other in the median. Sometimes the muscle ends in an aponeurosis connected with the musculus intermandibularis anterior.

2a. Surface of the area of attachment. This area to the lower jaw is perhaps flat.

2b. Surface of the area of attachment. This area on the tongue-bone is not mentioned.

3. Mutual course of the muscle fibres. The angle of the muscle fibres at the place of implanting on the lower jaw is acute.

g. Musculus genio-trachealis

(Dullemeijer, 1956a, pp. 31-32; 1956b, pp. 417-418)

This muscle runs a) from the lower jaw, b) to the lateral side of the 3rd-6th tracheal cartilaginous rings.

1a. Musculous attachment. This occurs to the lower jaw.

1b. Musculous attachment. This occurs to the tracheal rings.

2a. Surface of the area of attachment. This area to the lower jaw is a small area without any clear demarcations on the bone; this area is in my opinion probably curved.

2b. Surface of the area of attachment. This area to the trachea is small and in my opinion very probably rounded.

(H I) vi. *Crotalus atrox* Baird & Girard and *Crotalus terrificus* Laur. (Serpentes; Reptilia)

a. Musculus adductor mandibulae externus profundus

(DULLEMEIJER, 1959, p. 903)

The main differences with this muscle in *Vipera berus* (L.) are the following.

3. Mutual course of the muscle fibres. They run in two different directions, the nervus trigeminus ramus mandibularis as in *Vipera* separating the fibres of this muscle from those of the musculus adductor mandibulae posterior. A comparable condition occurs in *Trimeresurus*.

b. Musculus retractor palatini

(DULLEMEIJER,1959, p. 907)

The main differences with this muscle in *Vipera berus* (L.) are the following.

1a. Musculous attachment. This occurs to a plate-shaped extension which lies on the margin of the sphenoid of the cerebral skull.

1b. Musculous attachment. This occurs to the flat lateral surface of the palatinum and on the dorsal surface of the medial condyle of the transversum.

(H I) vii. *Bitis arietans* Merrem (Serpentes; Reptilia)

a. Musculus levator pterygoidei

(DULLEMEIJER, 1959, p. 939)

The main differences with this muscle in *Vipera berus* (L.) are the following.

2a. Surface of the area of attachment. The area of this muscle with its big transverse section on the cerebral skull is expanded by an enlargement of the basal part of the processus postorbitalis, the muscle being attached to the ventral part of this enlargement.

(H I) viii. *Phasianus colchicus* L. (Galli; Aves)

a. Musculus stylohyoideus

(BURGGRAAF, 1954, p. 676)

This part of the musculus mylohyoideus posterior runs a) from the lateral surface of the processus retro-articularis of the skeletal lower jaw, b) to the hyoid (urohyale). This part is more strongly developed than the part called the musculus serpihyoideus.

1a. Musculous attachment. This occurs to the lateral surface of the processus retro-articularis. The small muscle runs along this lateral surface to which in addition this muscle is attached by means of loose connective tissue.

1b. Musculous attachment. For the ventral branch of the muscle this occurs to the ventral side of the hyoid and for the dorsal branch to the dorsal side of the hyoid.

2a. Surface of the area of attachment. There are no special surface structures on the skeleton.

2b. Surface of the area of attachment. There are no special surface structures on the skeleton.

3. Mutual course of the muscle fibres. The fibres of this muscle lie across the muscle fibres of the musculus serpihyoideus. The muscle fibres are curved, as they run from the lateral surface of the processus retro-articularis over the ventral edge of the processus and proceed in a medio-rostral direction. After this curve the muscle is divided into two parts, a ventral and a dorsal branch.

b. Musculus geniohyoideus

(Burggraaf, 1954, pp. 676/677)

This muscle runs a) from the lower jaw, b) to the cornua of the hyoid arch. The rather long muscle consists of two sharply separated parts, a pars dorsalis and a pars ventralis, both fairly well developed, the pars dorsalis somewhat more strongly than the pars ventralis.

1a. Musculous attachment. The pars dorsalis is attached to the medial surface of the lower jaw. The pars ventralis is also musculously attached to the medial surface and to the ventral edge of the lower jaw.

1b. Musculous attachment. Of both parts together this occurs to the cornua of the hyoid arch.

2a. Surface of the area of attachment. There are no special surface structures on the skeleton.

2b. Surface of the area of attachment. There are no special surface structures on the skeleton.

3. Mutual course of the muscle fibres. Those of the pars dorsalis run in a caudal and slightly ventral direction, those of the pars ventralis in a caudal direction. The muscle fibres are curved round the cornua of the hyoid arch in an indistinct spiral; seen from the rostral side the course of the spiral is ventral-medial-dorsal-lateral.

Heading II: internal aponeurosis — internal aponeurosis

(H II) i. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus adductor mandibulae externus profundus

(Davids, 1952, pp. 90-92)

This muscle runs in a sharply ventral, slightly rostral and slightly lateral direction. Together with the musculus adductor mandibulae posterior and the musculus pseudotemporalis profundus it forms a muscular complex which runs a) from the lateral side of the quadratum, b) to the lateral surface of the lower jaw behind the processus coronoideus. The musculus adductor mandibulae externus profundus is the most caudal one of the three and has the most lateral position.

1a. Attachment by means of an internal aponeurosis. This aponeurosis (11) is probably an internal aponeurosis, as this aponeurosis (11) is attached to a tuber (11).

1b. Attachment by means of an internal aponeurosis. This aponeurosis (15) is probably an internal aponeurosis, as this aponeurosis (15) is attached to a tuber (15). This strong aponeurosis (15) is convex at the caudal side. Tuber (15) lies on the rostral border of the processus mandibularis externus.

2a. Surface of the area of attachment. The "tuber" (11) has the shape of a tuber.

2b. Surface of the area of attachment. The "tuber" (15) has the shape of a tuber.

Heading III: external aponeurosis — external aponeurosis

No examples of muscles lying entirely within the head and attached to the skull at both ends, are given in the literature mentioned.

Heading IV: musculous — internal aponeurosis

(H IV) i. *Squalus acanthias* L. (Squaliformes; Pisces)

a. Musculus constrictor maxillaris

(Van den Assem, 1952, p. 669)

This muscle runs a) from the lower jaw, b) to the median plane.

1a. Musculous attachment. This occurs to the right and left cartilaginous lower jaw.

1b. Attachment by means of an internal aponeurosis. The attachment in the ventral median plane to the horizontal aponeurosis can be considered an internal aponeurosis.

2a. Surface of the area of attachment. This area on the lower jaw is not described in detail.

2b. Surface of the area of attachment. This area of attachment of the internal aponeurosis is not described.

3. Mutual course of the muscle fibres. They run almost parallel to each other.

b. Musculus constrictor hyoideus

(Van den Assem, 1952, p. 669)

This muscle runs a) from the right and left cartilaginous hyoid, b) to the median plane.

1a. Musculous attachment. This occurs to the cartilaginous hyoid.

1b. Attachment by means of an internal aponeurosis. The attachment in the ventral median plane to the horizontal aponeurosis can be considered an internal aponeurosis.

2a. Surface of the area of attachment. This area to the hyoid is formed by the flat medial surface of a wing of the hyoid.

2b. Surface of the area of attachment. This area of attachment of the internal aponeurosis is not described.

3. Mutual course of the muscle fibres. The muscle fibres run almost horizontal in the ventral median part; then they curve round more dorsalwards and finally they run in a more dorsal direction. Attachment to the wing of the hyoid occurs at acute angles. In the caudal part the muscle fibres run almost perpendicularly to the median axis, in the rostral part at a more acute angle.

(H IV) ii. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor operculi

(Sarkar, 1960, pp. 52, 113)

This muscle runs a) from the ventral surface of the anterior arm of the temporal process, b) to the entire ridge of the caudo-dorsal part of the triangular crista (2) of the operculum. This triangular muscle is narrow towards its dorsal attachment and broad ventrally.

1a. Musculous attachment. This occurs to the cerebral skull, ventrally to the temporal process; the area of attachment is situated on the ventral surface of the base of the temporal process.

1b. Attachment by means of an internal aponeurosis. This aponeurosis (22) is perhaps an internal aponeurosis, judging by the figure and the note that divergent lateral muscle fibres are attached to the aponeurosis very close to the crista (2) and short medial fibres attached to the aponeurosis (22) halfway along the length of the muscle. The aponeurosis (22) is attached to the ridge of crista (2) at an angle of 90°. When an aponeurosis is attached to the edge of a bone, the attachment is usually to the general plane of the bone.

2a. Surface of the area of attachment. This area is a short and rounded fossa; the fossa has no distinct border structures.

2b. Surface of the area of attachment. This crista (2) is not described in detail.

3. Mutual course of the muscle fibres. This course is determined by the fact that the muscle is triangular, narrow towards its dorsal attachment and broad ventrally; especially the lateral muscle fibres diverge from their dorsal attachment.

(H IV) iii. *Rana esculenta* L. (Salientia; Amphibia)

a. Musculus pterygoideus

(Cool, 1953, p. 241)

This muscle runs a) from the prooticum and the fronto-parietale, b) to the lower jaw.

1a. Musculous attachment. This occurs to the medio-rostral part of the prooticum and the fronto-parietale.

1b. Attachment by means of an internal aponeurosis. This attachment to the lower jaw occurs by means of an aponeurosis which in my opinion is an internal tendon.

2a. Surface of the area of attachment. This lies on the in my opinion probably concave caudo-medial wall of the orbita of the skull. The dorsal border of the area of attachment on the skull follows the curve in the rostro-caudal crista on the fronto-parietale.

2b. Surface of the area of attachment. This area of the very long aponeurosis — in my opinion a tendon-like internal aponeurosis — lies on a separate ossification of the convex Meckel's cartilage, quite near the goniale, lying on the medial surface of the tuberculum praeglenoidale (in one specimen it lies on the border of the goniale as well as on the cartilage laterally of it).

(H IV) iv. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus pterygoideus ventralis lateralis

(Davids, 1952, pp. 529-530)

This muscle runs in a horizontal direction a) from the dorsal part of the processus angularis internus of the lower jaw, b) towards the caudo-ventral angle of the maxillare.

1a. Musculous attachment. This occurs on the posterior part of the ventral surface of the dorsal part of the processus angularis internus; this dorsal part extends from the medial border of the articulatio quadrato-mandibularis in a medio-dorso-caudal direction.

1b. Attachment by means of an internal aponeurosis. The long aponeurosis is probably an internal tendon; this tendon is attached to the caudo-ventral angle of the maxillare.

2a. Surface of the area of attachment. The ventral surface of the dorsal part of the processus angularis internus shows a concave aspect.

2b. Surface of the area of attachment. No detailed description of the angle is given.

3 Mutual course of the muscle fibres. The fibres hun parallel in a horizontal direction.

Heading V: musculous — external aponeurosis

(H V) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor mandibulae Al

(Sarkar, 1960, pp. 29-31)

This muscle part runs a) from the posterior rim of the ventral one-third of the prae-operculum, covering the entire ventro-lateral surface of the bone, b) to the upper, dorso-caudal, processus primordialis of the lower jaw. This muscle part is thick and rectangular.

1a. Musculous attachment. This occurs to the whole ventral part of the praeoperculum to the ventral and ventro-caudal surface of the praeoperculum. The area of attachment is roughly the shape of an elongated triangle, the sides of which are formed by the caudal and ventral edges of the praeoperculum and a line running halfway between this ventral edge and the upper costa (1).

1b. Attachment by means of external aponeuroses. The two surface aponeuroses to the medial surface of the processus primordialis are no doubt external aponeuroses; both are attached to the same region but one is above the other. The dorsally attached aponeurosis (1) is the rostral one, is short and runs caudo-ventrally. The ventrally attached bigger aponeurosis (2) is the caudal one, is long and runs posteriorly; it is a dorsal surface-aponeurosis.

2a. Surface of the area of attachment. The attachments of the muscle fibres are not very firm where the surface of the bone is flat and smooth, but they are very strong in the part where there are costae, generally in the posterior part of the praeoperculum. The muscle fibres are attached to both sides of each fine costa, but not to the upper surface of it.

2b. Surface of the area of attachment. This area is narrow, rectangular and restricted to a short space on the rounded dorsal surface of the processus primordialis. The angle of the aponeurotic attachments to the lower jaw are very acute.

3. Mutual course of the muscle fibres. The muscle fibres attached to the short rostral aponeurosis (1) run ventrally and are attached to the anterior part of the praeoperculum; this ventral attachment occupies a short area between the anterior one-third of the costa (1) and the ventral rim of the praeoperculum.

The muscle fibres from the major part of the long caudal aponeurosis (2) are all directed ventrally at an angle of about 90° to the aponeurosis; the posterior muscle fibres are directed more ventro-caudally, some of the most posterior muscle fibres being almost in a straight line with the aponeurosis.

The medial muscle fibres are shorter than the lateral muscle fibres.

b. Musculus adductor mandibulae part A3

(Sarkar, 1960, pp. 35-36, 113)

This muscle part runs a) from three different posterior positions on the parasphenoid, on the hyomandibula and on the quadratum and metapterygoid, b) to the rostral aponeurosis (3) of the muscle part A2. It runs along the lateral side of the dorso-median line of the cranium. This muscle part is broad rectangular.

1a. Musculous attachment. This attachment of portio I of the muscle part occurs to the prominent and irregular lateral process of the parasphenoid.

Attachment in a musculous way of portio II of the muscle part to the dorsal head of the hyomandibula, partly to the dorso-lateral posterior border of the hyomandibula and partly to the medial surface of the caudal half of the dorsal rim of the hyomandibular crest; some muscle fibres are attached to the dorsal part of the shaft of the hyomandibula. The entire area is semi-circular.

Attachment in a musculous way of portio III of the muscle part to the lateral surface of the dorsal half of the quadratum and the ventral half of the metapterygoid. The area of attachment is broad and more or less rectangular.

1b. Attachment by means of an external aponeurosis. This occurs by means of the aponeurosis (5) which in my opinion may be an external aponeurosis, judging from the figures. This aponeurosis (5) is thickened in the centre and is called mid-tendon here (ten. 1). This tendinous structure can be called an effect of the thickening of the aponeurosis along the longitudinal border. This aponeurosis (5) runs from its rostral attachment caudally and becomes broader in dorso-ventral direction. The aponeurosis (5) is attached to the lower jaw through the lateral surface of the rostral aponeurosis (3) of muscle part A2. The attachment of aponeurosis (5) to the aponeurosis (3) makes an angle of about 45°. The fusion of the aponeuroses of the muscles A1mβ, A2 and A3 takes place just caudally to the place of attachment on the lower jaw.

2a. Surface of the area of attachment. The surface of the approximately square area of musculous attachment on the lateral half of the process of the parasphenoid is rough and irregular.

The surface of the semi-circular area of musculous attachment of portio II of this muscle part is not described in detail.

The surface of the broad and more or less rectangular area of musculous attachment of portio III is not described in detail.

3. Mutual course of the muscle fibres. This mutual course may be indicated by the following notes.

The lateral muscle fibres of portion I of this muscle from the aponeurosis (5) are directed caudo-medially to the parasphenoid. A bundle of muscle fibres of the anterior part of the posterior half of portion I, instead of taking a straight caudal course like other muscle fibres, runs a little caudo-dorsally. These muscle fibres start from the mid-tendon, and make an angle of approximately 45° with it.

The muscle fibres of portion II diverge from the mid-tendon (ten. 1) as well as from the aponeurosis (5) to the hyomandibula. There is a dorsal elevation on the caudo-ventral region, the fibres of which are attached to the anterior half of the rostro-dorsal edge of the crista hyomandibularis, very close to the aponeurotic attachment of muscles A1mβ and A2. Laterally, from the posterior part of the mid-tendon, the muscle fibres run towards the top of the elevated region and then slope down laterally to be attached to the crista hyomandibularis. The remaining fibres of this portion, which are attached to the long shaft of the hyomandibula, are directed caudally from the aponeurosis.

The muscle fibres of the small and thin portio III start from the ventral part of the aponeurosis (5) and run in a ventro-caudal direction. A few rostro-medial muscle fibres of this portion are connected to the periosteum of the anterior side of the suspensorium below the rostral part of the aponeurosis (5).

The musculus adductor mandibulae A2 and A3 show an alternation of aponeuroses.

c. Musculus geniohyoideus pars posterior

(SARKAR, 1960, pp. 53-55, 113)

This muscle part runs a) from the connective tissue plate standing crosswise on a level with the angularia, from a mid-ventral connective tissue band, from the angulare and the dentale, b) to the ceratohyale, the 1st and the 2nd branchiostegal rays. This muscle part is triangular.

1a. Musculous attachment. This attachment takes place to a circular caudal flat surface which forms the area of attachment.

Attachment in a musculous way to an approximately rectangular area of attachment on the dentale; it lies on the dorsal surface of costa (3), a short distance anterior to the articulation of the lower jaw.

1b. Attachment by means of external aponeuroses. The three separate aponeuroses are perhaps external aponeuroses. One of the three is attached to the short triangular process, crista (5); its top is taken up entirely by the area of attachment; this crista (5) lies on the ventro-caudal part between the origins of the 1st and 2nd branchiostegal rays; the sharp edge of the crista (5) is directed ventrally.

Attachment by means of two of the three separate aponeuroses, which are perhaps external aponeuroses, to the 1st and 2nd branchiostegal rays, which have short ridged areas (tubers) on their antero-ventral surfaces, very close to their origin on the caudal part of the ceratohyale. The area of attachment takes up the tops of the tubers on the 1st and 2nd branchiostegal rays.

3. Mutual course of the muscle fibres. The muscle fibres converge from the anterior places of attachment to the aponeuroses.

(H V) ii. *Rana esculenta* L. (Salientia; Amphibia)

a. Musculus adductor mandibulae externus

(Cool, 1953, pp. 228-232)

This muscle runs a) from the processus zygomaticus and the "handle" of the squamosum and the cartilaginous anulus tympanicus on the one hand, b) to the lower jaw on the other hand.

1a. Musculous attachment. This occurs to the processus zygomaticus of the squamosum and to the "handle" of the squamosum and to the cartilaginous anulus tympanicus.

1b. Attachment by means of an external aponeurosis. The aponeurosis to the lower jaw is in my opinion probably an external aponeurosis.

2a. Surface of the area of attachment. This consists of three parts. In the first place we find the — in a few cases — slightly excavated medial surface of the ventro-rostralward directed processus zygomaticus of the squamosum showing a fossa (in other specimens a musculous attachment occurs on the rostrally extended narrow place of attachment at the proximal end of which the above-mentioned shallow excavation could not be detected). In the second place the area of attachment occupies a part of the slightly convex medial surface of the cartilaginous anulus tympanicus, in some specimens occupying the full breadth of the rostro-ventral quadrant of the ring, in other specimens occupying a long and narrow part of its medial surface only (in the latter specimens the attachment to the "handle" of the squamosum is lacking). In the third place the area of attachment is found on the medial surface of the "handle" of the squamosum, *i.e.* the ventro-caudally directed processus of the squamosum; this long and narrow place of attachment is restricted to the rostral border of this "handle".

2b. Surface of the area of attachment. This area of attachment of the in my opinion probably external aponeurosis is found along a long, narrow, caudo-ventralwards curved place of attachment lying on the convex lateral surface of Meckel's cartilage and on the in my opinion probably plane surface of the goniale. For the greater part the attachment on the goniale is situated on the dorsal surface of a crista formed by the ventral border of the goniale which is curved laterally and which forms a narrow sharp edge which may be called a crista and transgresses for a small distance dorsalwards on the lateral surface of the goniale situated dorsally of the above-mentioned crista.

(H V) iii. *Vipera berus* (L.) (Serpentes; Reptilia)

a. Musculus adductor mandibulae externus medialis

(Dullemeijer, 1956a, p. 16; 1956b, p. 402; personal communication)

This muscle runs a) from the cerebral skull and the supratemporale, b) to the lower jaw.

1a. Musculous attachment. This occurs to the cerebral skull and to the supratemporale.

1b. Attachment by means of an external aponeurosis. The attachment of this aponeurosis (according to a personal communication this aponuerosis is an external one) occurs to the lower jaw. This external aponeurosis lies with its base at a very short distance from the low medial plane of the V-shaped gutter-like external aponeurosis of the second part of the musculus adductor mandibulae externus superficialis or it is even fused with this medial plane. In both cases the aponeurosis of the musculus adductor mandibulae externus medialis is a plate-like external aponeurosis which is found on the medial side of the medial plane of the V-shaped gutter-like external aponeurosis of the second part of the musculus adductor mandibulae externus superficialis (personal communication). The note on the tangential attachment of the aponeurosis to the lower jaw, probably refers to the aponeurosis which is directly attached to the lower jaw (1956a, p. 106; 1956b, p. 492).

2a. Surface of the area of attachment. This area on the cerebral skull and on the supratemporalia is very narrow. These surfaces are probably rounded.

2b. Surface of the area of attachment. This area of the aponeurosis on the lower jaw and the attachment of a small part of the aponeurosis to the corner of the mouth, is narrow.

3. Mutual course of the muscle fibres. This course is such that the muscle is broad and flat, but ventralwards becomes cylindric.

b. Musculus intermandibularis ventralis

(DULLEMEIJER, 1956a, pp. 29-30; 1956b, pp. 415-416)

This muscle runs a) from the median line ventral to the trachea, b) to the lower jaw.

1a. Musculous attachment. The attachment to the connective tissue in the median line ventral to the trachea and connected with the trachea very probably is a musculous one.

1b. Attachment by means of an external aponeurosis. The common aponeurosis of a number of muscles is an external aponeurosis (personal communication). This aponeurosis is attached to the lower jaw and continues on the lateral surface of the periost to which it is strongly connected.

2b. Surface of the area of attachment. This area of the aponeurosis is the very narrow ventral ridge of the dentale.

(H V) iv. *Columba palumbus palumbus* L. (Columbae; Aves)

a. Musculus adductor mandibulae externus medialis

(ROOTH, 1953, pp. 253-254, 264; personal communication)

This muscle runs a) from the lateral surface of the lower jaw in a caudal and somewhat dorsal direction, b) to the processus temporalis.

1a. Musculous attachment. This occurs to an area on the lateral surface of the lower jaw which is rather long and has the shape of a low triangle; rostralwards this area of attachment becomes gradually narrower and ends as a point. This area is bounded caudo-dorsally by a crista (10) which begins at spina (9) of the musculus adductor mandibulae externus superficialis and runs latero-caudo-ventralwards; this crista (10) is the place of attachment of the musculus adductor mandibulae externus profundus.

1b. Attachment by means of an external aponeurosis. This aponeurosis (6) is no doubt an external surface aponeurosis (personal communication) and is attached to the rostral part of the processus temporalis. This aponeurosis (6) is narrow;

it becomes broader in a rostro-ventral direction, so that in its course more and more muscle fibres find their attachment on its rostro-dorsal surface.

2a. Surface of the area of attachment. This surface is somewhat excavated, deepest in the caudal part, where it also has its greatest height. Rostralwards the hollow surface passes into a flat and even into a somewhat convex plane.

2b. Surface of the area of attachment. No detailed description of the shape of the processus is given.

b. Musculus adductor mandibulae externus profundus

(ROOTH, 1953, pp. 254-255, also p. 252; personal communication)

This muscle runs a) from the squamosum in a rostro-ventral direction, b) to the dorsolateral surface of the lower jaw.

1a. Musculous attachment. This occurs to the central part of the crescent or yoke-shaped area of attachment on the squamosum, the outer peripheral part of which is occupied by the origin of the pars superficialis of the musculus adductor mandibulae externus.

1b. Attachment by means of an external aponeurosis. The aponeurosis (10) is no doubt an external superficial aponeurosis, as the muscle fibres are attached to the dorso-rostral side of this broad aponeurosis (personal communication). This aponeurosis (10) is attached to crista (10), which lies at the caudal boundary of the area of attachment of the musculus adductor mandibulae externus medialis.

2a. Surface of the area of attachment. This area on the squamosum as a whole has the shape of a crescent or a yoke, the convex side of which is directed dorso-caudally.

2b. Surface of the area of attachment. The crista (10) has the shape of a crista.

3. Mutual course of the muscle fibres. They converge to some extent, constituting a broad, flat bundle.

c. Musculus adductor mandibulae internus pseudotemporalis superficialis

(ROOTH, 1953, p. 256; personal communication)

The superficialis part of this muscle runs a) from the wall of the orbita in a rostrolateral direction, b) to the lower jaw.

1a. Musculous attachment. This occurs to a nearly triangular area, dorsomedially of foramen V1.

1b. Attachment by means of an external aponeurosis. The aponeurosis is no doubt an external aponeurosis, as the muscle fibres are attached to the ventro-caudal surface of the forked aponeurosis (personal communication). The attachment takes place to two spinae (7) and (8) by means of the tendinous ends of the two "prongs" of a fork-shaped aponeurosis. The two equally strong "prongs" taper in the direction of the spinae. The unpaired base of the "fork" increases in breadth in a caudal direction. These two spinae, lying opposite each other, are situated rostro-medially of the area of attachment of the musculus adductor mandibulae externus superficialis. Especially on the broad part of the aponeurosis a great number of muscle fibres find their attachment.

2a. Surface of the area of attachment. This is slightly convex.

2b. Surface of the area of attachment. The spinae (7) and (8) have the shape of spinae.

d. Musculus adductor mandibulae internus pseudotemporalis profundus

(Rooth, 1953, pp. 256-257; personal communication)

The profundus part of this muscle runs a) from the medial surface of the lower jaw in a caudo-dorso-medial direction, b) to the quadratum.

1a. Musculous attachment. This occurs to an extensive area on the medial surface of the lower jaw, medially of the ramus mandibularis of the nervus trigeminus. This area of musculous attachment is elliptical and situated with its long axis parallel to the longitudinal axis of the lower jaw.

1b. Attachment by means of an external aponeurosis. This aponeurosis is no doubt an external aponeurosis, as the muscle fibres are attached on its dorsal side (personal communication). It is attached to crista (1) on the most rostro-medial part of the processus orbitalis of the quadratum. This aponeurosis is broad and rather short.

2a. Surface of the area of attachment. This area is probably a flat plane.

2b. Surface of the area of attachment. The crista (1) is somewhat curved

Heading VI: internal aponeurosis — external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading VII: musculous — musculous + internal aponeurosis

(H VII) i. *Columba palumbus palumbus* L. (Columbae; Aves)

a. Musculus adductor mandibulae internus pterygoideus

(Rooth, 1953, pp. 257-259; personal communication)

This muscle runs a) from the dorsal and the ventral surface of the lateral wing of the palatinum, b) to an area of attachment on the medial surface of the lower jaw. This occurs on the lateral *resp.* on the medial side of this area on the lower jaw.

1a. Musculous attachment. This occurs on both surfaces of the lateral wing of the palatinum. The area of musculous attachment to the dorsal surface of the lateral wing of the palatinum is rather long and its breadth is inconsiderable, but remains the same along the whole of its length; only the rostral end is somewhat rounded.

The area of musculous attachment to the ventral surface of the lateral wing of the palatinum is also long and narrow and somewhat pointed at its rostral end.

1b. Musculous attachment. This occurs on a large area on the medial surface of the lower jaw; this shows a lateral and a medial side on this area of attachment for the two bundles of the muscle.

The area of musculous attachment of the dorsal and the ventral bundle is extensive. The area of the dorsal bundle transgresses on the ventral and even partly on the lateral surface of the lower jaw. This part on the lateral surface of the lower jaw is situated on the caudo-ventral part of the lower jaw.

Attachment by means of an internal aponeurosis. The attachment of both bundles of the muscle occurs by means of the aponeuroses (14) and (13) which are no doubt both internal aponeuroses (personal communication). The base of the aponeurosis (14), no doubt an internal one, is entirely surrounded by the area of musculous attachment. On the aponeurosis (13), no doubt an internal one, the muscle fibres are attached to the dorsal and ventral surfaces of this aponeurosis (13). The aponeurosis (14) is attached on the lower jaw to a ridge (14) which runs in a ventro-rostral direction from the medio-rostral side of the cavitas glenoidalis. The attachment of aponeurosis (13) which is short and broad, takes place on the lower jaw; this aponeurosis is attached to a crista (13) on the processus articularis internus of the lower jaw.

2a. Surface of the area of attachment. Both areas are no doubt flat planes.

2b. Surface of the area of attachment. The area of musculous attachment is very probably a flat plane, turning round the ventral edge of the lower jaw.

The ridge to which the aponeurosis (14) is attached is small and not very prominent. The crista (13) has no doubt the shape of a crista.

3. Mutual course of the muscle fibres. That of the muscle bundle which starts from the dorsal surface of the lateral wing of the palatinum, is directed from medio-rostral to latero-caudal.

The direction of the muscle fibres of the muscle bundle which starts from the ventral surface of the lateral wing of the palatinum is from rostral to caudal.

b. Musculus protractor quadrati et pterygoidei

(ROOTH, 1953, pp. 260-261; personal communication)

This muscle runs a) from the wall of the orbita, b) to the quadratum and the pterygoid.

1a. Musculous attachment. This occurs partly on the septum interorbitale and partly on the caudal wall of the orbita on a fairly extensive area. The attachment of the musculus protractor quadrati occupies the more latero-caudal part of this common area, that of the musculus protractor pterygoidei the more medio-rostral part.

1b. Musculous attachment. This attachment in a perfectly musculous way of the musculus protractor quadrati occurs on the whole of the caudo-ventral surface of the processus orbitalis of the quadratum.

Attachment by means of an internal aponeurosis. The slightly developed aponeurosis of the musculus protractor pterygoidei is no doubt an internal aponeurosis; the muscle fibres are attached to the lateral and medial surface of this aponeurosis. This aponeurosis is attached to a crista situated on the dorsal part of the pterygoid.

2a. Surface of the area of attachment. This area on the wall of the orbita is no doubt a hollow surface in two directions, in the dorso-ventral direction as well as especially also in the medio-rostral direction.

2b. Surface of the area of attachment. This area on the processus orbitalis of the quadratum is no doubt a curved plane.

The crista on the pterygoid has no doubt the shape of a crista.

3. Mutual course of the muscle fibres. The direction of the muscle fibres of the musculus protractor quadrati is such, that muscle fibres which at the origin are the most dorsal ones, also have the most dorsal insertion. — The direction of the muscle fibres of the musculus protractor pterygoidei is latero-caudo-ventrad.

4.5. Because of the relative position of the opposite areas of attachment and because of the extensiveness of these areas of attachment, the direction of the muscle fibres is rather varying. The extremes on both sides are as follows: (a) from the most latero-caudal part of the area of origin the muscle fibres run in a latero-rostral and also somewhat ventral direction; (b) from the most medio-rostral part the course of the muscle fibres is lateralwards and somewhat ventral- and even somewhat caudalwards. In the intermediate area all possibilities of transition between these two extremes have been realized.

(H VII) ii. *Phasianus colchicus* L. (Galli; Aves)

a. Separate muscle bundle between the area round the pterygoid-palatinum articulation and the distal end of the processus angularis internus

(Fuchs 1954, p. 470)

This small more or less separate muscle bundle runs a) from the area round the pterygoid-palatinum articulation, b) to the processus angularis internus in a latero-caudal direction.

1a. Musculous attachment. This occurs to an extremely small place in the immediate vicinity and round the palatinum-pterygoid articulation, thus on the palatinum and the pterygoid.

1b. Musculous attachment. This occurs to a place on the processus angularis internus dorso-rostrally of crista (19).

Attachment by means of an internal aponeurosis. This aponeurosis (19a) is attached about parallel to crista (19) to the bony surface; sometimes it is connected at its base with aponeurosis (19). The length of aponeurosis (19a) is maximally 5 mm, but generally it is shorter.

A few muscle fibres are attached to the dorsal surface of aponeurosis (19), close to its attachment to crista (19); this aponeurosis is for the greatest part a dorsal surface aponeurosis; thus the aponeurosis (19) is an internal aponeurosis.

2a. Surface of the area of attachment. No detailed description is given.

2b. Surface of the area of attachment. At the base of the attachment of aponeurosis (19a) the bony surface does not show any special structure.

3. Mutual course of the muscle fibres. The direction of the muscle fibres is slightly curved.

b. Musculus protractor quadrati et pterygoidei

(Fuchs, 1954, pp. 666-668; personal communication; Burggraaf & Fuchs, 1955, p. 98)

This rather strongly developed muscle runs a) from the ventro-rostral surface of the cerebral skull and the caudo-ventral part of the septum interorbitale, b) towards the caudo-medial surface of the quadratum and the medio-caudal surface of the pterygoid. It runs in a caudo-ventro-lateral direction.

1a. Musculous attachment. This occurs to the cerebral skull, extending from the caudo-ventral part of the septum interorbitale ventro-caudo-lateralwards as far as near the cavum tympani. The area of attachment is bordered caudo-dorsally by several foramina for some cerebral nerves and rostro-ventrally by the processus basipterygoideus.

1b. Musculous attachment. This occurs to the fossa corporis quadrati and to the processus articularis quadrati as far as close near spina (6).

Attachment in a musculous way to the pterygoid near the quadratum rostro-latero-dorsally of crista (A); rostro-medially, however, the area of attachment is situated on either side of this crista (A); the area of attachment extends as far as about half way up the pterygoid.

Attachment by means of an internal aponeurosis. The aponeurosis (A) is an internal aponeurosis, though it is mainly a ventral surface aponeurosis, but at some distance of the quadratum it also bears on its ventral surface a limited number of muscle fibres (personal communication). This aponeurosis (A) is rather strongly developed; on its lateral side it is shorter (2.5 mm) than more medially (6.0 mm). Aponeurosis (A) is attached to crista (A) and to spina (A), which occurs in some cases.

2a. Surface of the area of attachment. This area on the cerebral skull consists of two contiguous concave surfaces.

2b. Surface of the area of attachment. This area on the quadratum has the shape of a fossa. The surface of musculous attachment on the processus articularis quadrati is, according to the figure, perhaps also hollow. The surface of musculous attachment on the pterygoid is, according to the figure, perhaps a flat plane.

Crista (A) is situated on the medio-caudal surface of the caudo-lateral end of the pterygoid. Crista (A) runs from the articulation of the pterygoid with the quadratum towards the articulation with the processus basipterygoideus; the course and position of crista (A) are highly variable.

Spina (A) is not always equally distinct; it is situated near the caudo-lateral end of the pterygoid.

Heading VIII: musculous — musculous + external aponeurosis

(H VIII) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus levator arcus palatini

(Sarkar, 1960, pp. 42-44)

This muscle runs a) from the dorso-medial surface of the crista hyomandibularis (mainly along its upper rim) and from the roughened area near the angle between the base of the temporal process and the hyomandibula, b) towards the entire ventral surface of the squamosal process. The thick and round anterior portion of the muscle is directed dorso-ventrally and shows a very short dorso-ventral length. The thin and flat posterior portion of the muscle is directed approximately antero-posteriorly.

1a. Musculous attachment. This occurs to the medial surface of the rostro-lateral projection of the crista hyomandibularis by the anterior portion of the muscle. The rostral, lateral and medial bundles of muscle fibres of the anterior portion of the muscle run in a straight line from the crista hyomandibularis to the ventral surface of the squamosal crest without any fusion at either end. This is possible because the areas for attachment are almost equally large at both ends. Some posterior bundles of the anterior portion are directed slightly caudo-ventrally to the crista hyomandibularis.

Attachment in a musculous way to the medial surface of the upper rim of the crista hyomandibularis of the muscle fibres of the rostro-medial bundles of the posterior portion of the muscle (this musculous attachment takes place by means of a connective tissue plate: it is doubtful whether, morphologically speaking, it can be called an aponeurosis); the area of attachment is very narrow.

1b. Musculous attachment. This shows the anterior part of the muscle to the ventral surface of the squamosal process; the area of attachment is rectangular and uneven and lies on the lateral half of this ventral surface.

Attachment in a musculous way of the posterior part of the muscle to the ventro-caudal surface of the squamosum; this area of attachment is narrow.

Attachment in a musculous way of a few bundles of muscle fibres just ventral to the rostro-medial bundles to the caudo-ventral surface of the squamosal process ventral to the aponeurosis (16).

Attachment by means of an external aponeurosis. This occurs by means of the aponeurosis (16), which is in my opinion perhaps an external aponeurosis, as it lies on the margin of the area of musculous attachment on the squamosal process. This aponeurosis (16) is attached to crista (1), a short rounded projection near the middle region or a short process of the caudal surface of the squamosal process; the caudal surface of the squamosal process bears this crista (1). The remaining medial area of the squamosal process from crista (1) is the surface of attachment for the posterior portion of this muscle (the area lateral to crista (1) of the squamosal process is occupied by attachment of the caudal part of the musculus dilatator operculi pars lateralis).

3. Mutual course of the muscle fibres. This is indicated by the following notes.

The muscle fibres are attached perpendicularly to the crista hyomandibularis.

Most of the dorsal fibres of the posterior portion are directed more antero-posteriorly than those of the anterior portion of the muscle. The muscle fibres of this posterior portion of the muscle run in different directions. The muscle fibres of the rostro-medial bundles of the posterior portion, which are attached to the short crista (1) of the squamosal process by the aponeurosis (16), run ventro-laterally from this aponeurosis to be connected with the medial surface of the upper rim of the crista hyomandibularis.

The muscle fibres of the remaining part of this posterior portion of the muscle which is thin and flat, are directed somewhat rostro-caudally and are attached at an angle of 60° to the caudal surface of the squamosal process behind crista (1) and on the opposite side to the rough, excavated area at the junction of the base of the temporal process and the hyomandibula.

b. Musculus levator operculi

(SARKAR, 1960, pp. 51-52, 113)

This rectangular muscle runs a) from the posterior surface of crista (4) and from the lateral surface of crista (2) of the operculum, b) to the anterior surface of the rostral arm of the temporal process. Its direction is from rostro-ventral to dorsal.

1a. Musculous attachment. This occurs on the entire caudal or posterior surface of crista (4) and a short distance on crista (3) of the operculum. The shape of the area of attachment is approximately rectangular.

Attachment in a musculous way on the caudal and the caudo-dorsal surface of crista (2) and part of crista (3) of the operculum.

1b. Musculous attachment. This occurs to the anterior surface of the rostral arm or to the anterior arm of the temporal process. This area of musculous attachment is long but narrow and rectangular. The lateral surface of the rostral arm of the temporal process serves as a place of attachment for the musculus levator operculi, but also for the musculus trapezius (the area being very narrow, it can be expected that a few posterior muscle fibres of the musculus levator operculi will have some aponeurotic attachment to the dorsal tendon of the musculus trapezius). The anterior lateral muscle fibres are attached to the rostral surface of the temporal process. The medial muscle fibres of this muscle have their dorsal attachment to the ventral surface of the anterior arm of the temporal process.

Attachment by means of an external aponeurosis. This occurs by means of the aponeurosis (21), which is in my opinion perhaps an external aponeurosis, judging from the marginal position of the aponeurosis indicated in the figure. This aponeurosis is attached to the anterior ridge on the lateral surface of the temporal process.

3. Mutual course of the muscle fibres. The attachments of the anterior lateral muscle fibres on the rostral surface of the temporal process and on the posterior surface of crista (4) of the operculum are made at angles of about 80°. The direction of the medial muscle fibres is similar to that of the lateral muscle fibres.

(H VIII) ii. *Vipera berus* (L.) (Serpentes; Reptilia)

a. Musculus adductor mandibulae internus pterygoideus

(DULLEMEIJER, 1956a, pp. 18-22; 1956b, pp. 404-408)

This muscle runs from a) the medial plane of the lower jaw, b) to the pterygoid, to the corner of the mouth and to the transversum. At this end the muscle shows four bundles.

1a. Musculous attachment. This occurs with three muscle bundles to the lower jaw. The bundles are attached to the medial plane of the lower jaw, ventral to the joint. Besides a little bundle of muscle fibres is attached to the connective tissue of the corner of the mouth.

1b. Musculous attachment. This occurs with one bundle to the pterygoid. A second bundle of this muscle is attached to the aponeurosis in the connective tissue of the corner of the mouth. A little bundle of muscle fibres is attached to the connective tissue around the poison-fang.

Attachment by means of an external aponeurosis. Attachment of a third and fourth bundle of this muscle to the transversum by means of a tendon which is probably an external one (personal communication) (according to DULLEMEIJER, 1959, p. 943, these two parts are to be understood as one bundle, as in the other Viperidae). This tendon branches off a small one to the connective tissue around the poison-fang.

2a. Surface of the area of attachment. This area on the medial plane on the lower jaw contains the attachment of three all but inseparable parts of the muscle. One part is attached in the groove, having about the same length as the articular surface and being a little curved. The second part of the area of attachment is flat and lies on the ventral side of the round edge of the rod of the lower jaw itself. The third part of the area of attachment lies on the small, almost pointed, rough place, lying a little more rostrally.

2b. Surface of the area of attachment. This area on the pterygoid lies along the whole breadth of its medial plane, mainly concentrated in the ventral groove. The pterygoid is wave-shaped in transverse section; it shows a medial groove, facing dorsally and a lateral one, facing ventrally. — The area of attachment of the tendon to the curved point of the transversum, if it is not rounded, has the shape of a spina (1956a, p. 106; 1956b, p. 492).

3. Mutual course of the muscle fibres. As far as they are musculously attached to the lower jaw, they show for the larger part of the fibres an attachment in an almost tangential way (1956a, p. 92; 1956b, p. 478; personal communication).

b. Musculus intermandibularis anterior

(DULLEMEIJER, 1956a, pp. 30-31; 1956b, pp. 416-417)

This muscle runs a) from the trachea, b) to the lower jaw. It constitutes the 3rd and 4th part of the musculus intermandibularis. There is a rostral and a caudal part.

1a. Musculous attachment. This occurs with the most rostral part of the muscle, which is attached to the connective tissue plate connected with the trachea. This plate can hardly be separated from the place of attachment of the musculus intermandibularis posterior with its aponeurosis.

1b. Musculous attachment. This occurs with the most rostral part in its attachment to the most rostral point on the latero-ventral plane of the lower jaw caudalwards to the median. As the most rostral part of the lower jaw is bent inwards, the place of attachment lies partly on the lateral surface of the lower jaw, partly on a connective tissue plate lying ventrally to the caudal part of this muscle.

Attachment by means of an external aponeurosis. This connective tissue plate may be considered as an aponeurosis. This aponeurosis is an external one (personal communication). The connective tissue plate is connected with the ligamentum intermandibulare and forms a part of the bottom of the mouth. — The most caudal part of this muscle is attached to the lower jaw in a musculous way as well as to the ligamentum intermandibulare.

2a. Surface of the area of attachment. This area on the trachea has not been described.

2b. Surface of the area of attachment. This area to the lower jaw of the most rostral part of the muscle is not sharply demarcated. That of the most caudal part of the muscle lies on the narrow ventro-rostral surface of the lower jaw.

3. Mutual course of the muscle fibres. That of the most rostral part shows a tangential attachment to the lower jaw. The muscle fibres of the most rostral part highly diverge caudalwards and then run parallel caudalwards. The muscle fibres of the more caudal part of the muscle highly converge and form a narrow bundle.

(H VIII) iii. *Crotalus atrox* Baird & Girard and *Crotalus terrificus* Laur. (Serpentes; Reptilia)

a. Musculus adductor mandibulae internus pterygoideus

(DULLEMEIJER, 1959, pp. 904-905, 943, 952)

The main differences with this muscle in *Vipera berus* (L.) are the following. The muscle is distinctly divided into four parts.

1a. Musculous attachment. This occurs with the four parts on the medial plane of the lower jaw.

Attachment by means of an aponeurosis. This occurs with the third part to the connective tissue in the corner of the mouth; this part is also attached to the connective tissue of the bag of the poison-gland, but not to the skeleton.

1b. Musculous attachment. This takes place with the rest of this first part on the lateral part of the ventral surface of the transversum. Attachment of the rest of the third part of the muscle on the dorso-medial side of the transversum. Attachment of the fourth part, the musculus adductor mandibulae internus pterygoideus accessorius is similar to that in *Vipera*. Thus there are two areas of attachment to the transversum which are both musculous.

Attachment by means of an aponeurosis. This occurs with the first, second and third part of the muscle on the rostro-lateral knob of the transversum. This aponeurosis is completely occupied by muscle fibres.

3. Mutual course of the muscle fibres. Those of the first part run parallel to the lower jaw.

(H VIII) iv. *Bitis arietans* Merrem (Serpentes; Reptilia)

a. Musculus adductor mandibulae internus pterygoideus

(DULLEMEIJER, 1959, pp. 906, 943, 954, 963)

The main differences with this muscle in *Vipera berus* (L.) are the following.

1b. Musculous attachment. The first part is musculously attached to the entire upper surface of the lateral wing of the transversum. The third part is musculously attached to the lower surface of the lateral wing of the transversum. Part of the muscle fibres are attached to the bag in which the teeth grow. There is only a very loose connection with the poison-gland. The musculus adductor mandibulae internus pterygoideus accessorius is rather small.

Attachment by means of an aponeurosis. This occurs with the second part which is attached to the edge of the lateral wing of the transversum.

(H VIII) v. *Trimeresurus albolabris* Gray (Serpentes; Reptilia)

a. Musculus adductor mandibulae internus pterygoideus

(DULLEMEIJER, 1959, pp. 906, 943, 954)

The main differences with this muscle in *Vipera berus* (L.) are the following.

The muscle is divided into four parts. The small first part is attached to the poison-gland.

1b. Musculous attachment. The third rather strong part is musculously attached to the ventro-rostral surface of the transversum.

Attachment by means of an aponeurosis. This occurs with the big second part which is attached to the maxilla. The fourth part, the musculus adductor mandibulae internus pterygoideus accessorius, is in its way of attachment similar to that in *Vipera*.

(H VIII) vi. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus pseudotemporalis profundus

(DAVIDS, 1952, pp. 90-92)

This muscle runs in a rostral-ventral-lateral direction. Together with the musculus adductor mandibulae posterior and the musculus adductor mandibulae externus profundus it forms a muscular complex which runs a) from the lateral surface of the lower jaw behind the processus coronoideus, b) towards the lateral side of the quadratum. The musculus pseudotemporalis profundus is the most rostral one of the three; it has the most medial position.

1a. Musculous attachment. This occurs in the first place at the height of the processus coronoideus on a triangular plane which extends dorsalwards as far as the superior border of the lower jaw, in the second place to the medial surface of the lower jaw on the caudo-dorsal side of the foramen V3.

1b. Musculous attachment. This occurs to the small oblong plane on the ventral side of crista (13) on the processus orbitalis quadrati.

Attachment by means of an external aponeurosis. The very thin aponeurosis is probably an external aponeurosis, as the crista (13) to which the aponeurosis is attached, lies on the dorsal border of the area of musculous attachment,

2a. Surface of the area of attachment. This area on the lower jaw seems to be saddle-shaped, according to the figures.

2b. Surface of the area of attachment. This area on the processus orbitalis quadrati is no doubt curved. The crista (13) is a low crista, also according to the figures.

3. Mutual course of the muscle fibres. The attachment of the muscle fibres to the medial surface of the lower jaw takes place at a very sharp angle.

b. Musculus protractor pterygoidei

(Davids, 1952, pp. 525-528)

The musculus protractor pterygoidei runs a) from an extended area on the ventral parts of the entirely ossified septum interorbitale, b) towards a smaller area on the posterior part of the pterygoid.

1a. Musculous attachment. This attachment to the ventral part of the septum interorbitale reaches rostralwards the planum antorbitale and extends ventralwards on the rostrum sphenoidale.

1b. Musculous attachment. This occurs with the caudo-ventral muscle fibres on the medial side of the crista (24), projecting from the pterygoid.

Attachment by means of an external aponeurosis. This occurs with aponeurosis (24) which is probably an external aponeurosis, as the muscle fibres are attached on the medial surface of the strong aponeurosis (24) which is attached to crista (24); this crista projects from the posterior part of the pterygoid. A very large part of the muscle fibres are attached to aponeurosis (24).

2a. Surface of the area of attachment. This area on the septum interorbitale is no doubt a concave plane.

2b. Surface of the area of attachment. Crista (24) is a small but distinct crista.

3. Mutual course of the muscle fibres. The fibres attached on the septum interorbitale show a very sharp angle of attachment. These muscle fibres converge in a caudal-ventral-less lateral direction.

(H VIII) vii. *Columba palumbus palumbus* L. (Columbae; Aves)

a. Musculus adductor mandibulae posterior

(Rooth, 1953, pp. 255-256, 264; personal communication)

This muscle runs a) from the dorsal and medial surface of the lower jaw in a rostroventral direction, b) to the quadratum.

1a. Musculous attachment. This occurs to an area lying just rostrally of the cavitas glenoidalis for the quadratum; the rostral border is formed by crista (10) and spina (9). This surface of attachment slopes upwards in a rostral direction.

1b. Musculous attachment. This area occupies a great part of the dorso-rostral surface of the quadratum *viz.* the part which is situated laterally of the ramus mandibularis of the nervus trigeminus.

Attachment by means of an external aponeurosis. This aponeurosis is no doubt an external aponeurosis (personal communication); it lies at the dorsal border of the area of musculous attachment. This aponeurosis is attached to crista (2).

2a. Surface of the area of attachment. No details are given.

2b. Surface of the area of attachment. This area on the quadratum is somewhat curved and consequently the attachment occurs partly on a concave and partly on a convex part of it. The crista (2) is minute.

(H VIII) viii. *Phasianus colchicus* L. (Galli; Aves)

a. Musculus adductor mandibulae internus pseudotemporalis profundus

(FUCHS, 1954, pp. 459-461; personal communication)

This not very strongly developed muscle runs a) from the medial surface of the lower jaw, b) to the distal end of the processus orbitalis quadrati.

1a. Musculous attachment. There is a long and rather high area of musculous attachment at the most rostral point reaching the dorsal border of the lower jaw; the most ventral border is the canalis primordialis.

1b. Musculous attachment. This is restricted to a small area of attachment on the distal end of the processus orbitalis quadrati on the dorso-lateral-rostral surface and on the ventral border of the processus.

Attachment by means of an external aponeurosis. This aponeurosis (14) is no doubt an external aponeurosis with one wall (personal communication). This medio-dorsal surface aponeurosis (14) is rather strongly developed and is attached at the rounded top of the processus orbitalis quadrati. On its ventral border the base of aponeurosis (14) sometimes shows an incision partly separating a small part, which we call aponeurosis (14a).

2a. Surface of the area of attachment. No details are given.

2b. Surface of the area of attachment. The place of attachment of aponeurosis (14) can hardly be characterized as a crista, unless the edge of the processus orbitalis quadrati were considered as such.

3. Mutual course of the muscle fibres. They converge medio-caudally.

(H VIII) ix. *Ardea cinerea* (L.) (Gressores; Aves)

a. Musculus adductor mandibulae posterior

(BAS, 1955, pp. 101-102; personal communication)

This muscle runs a) from the dorsal edge of the lower jaw, b) to the basal half of the processus orbitalis quadrati.

1a. Musculous attachment. This occurs to the dorsal flattened edge of the lower jaw; caudally this place of attachment is bordered by the most rostral cavity of the joint of the jaw; its caudo-medial border is formed by crista (19); it lies caudally of spina (7).

1b. Musculous attachment. This occurs to the narrow ventral edge of the basal half of the processus orbitalis quadrati and a triangular area on the lateral surface of this processus.

Attachment by means of an external aponeurosis. The aponeurosis (10) is no doubt an external aponeurosis with one wall (personal communication). This small surface aponeurosis (10) is attached to the small spina (10), which lies near the base of the processus orbitalis quadrati.

2a. Surface of the area of attachment. This area is slightly convex.

2b. Surface of the area of attachment. This area on the flattened basal half of the processus orbitalis quadrati, which is flattened in a medio-lateral direction and which shows a narrow ventral edge bent medialwards, is slightly concave; the narrow edge is slightly convex and the border between them is not a sharp edge.

The spina (10) is small.

3. Mutual course of the muscle fibres. The most caudo-lateral muscle fibres which are attached to the aponeurosis (10) run in a latero-ventral direction; the course of the more medio-rostral muscle fibres which are attached directly to the processus orbitalis quadrati, is directed somewhat more rostralwards.

b. Musculus protractor quadrati et pterygoidei

(BAS, 1955, pp. 110-112; personal communication)

A rostral part of this muscle runs a) from the latero-ventral surface of the cerebral skull and a caudal part of this muscle runs a) from the lateral wall of the tuba auditiva in a latero-caudal direction, b) to the medial surface of the quadratum as well as b) to the caudal end of the pterygoid. It is not possible to divide the muscle into a pars quadrati and a pars pterygoidei.

1a. Musculous attachment. This occurs to the latero-ventral surface of the cerebral skull and the lateral surface of the tuba auditiva. This place of attachment has about the outline of a lying sandglass. The rostral border of this area of attachment is the caudal rim of the foramen interorbitale just ventrally of the foramen nervi optici. The ventral border is formed by a crista, which runs from the rostrum sphenoidale caudalwards over the lateral surface of the skull base. The dorsal border is formed by a sudden lateralward expansion of the cerebral skull. The caudal border lies at a short distance from the rim of the bony aperture of the tuba auditiva.

1b. Musculous attachment. This occurs to the medial surface of the quadratum. This place of attachment is triangular; the rostral point lies halfway up the processus orbitalis; the ventral point reaches as far as on the dorsal surface of the processus pterygoideus and the caudo-dorsal point as far as near to the medial condylus of the quadratum-squamosum joint. The caudal border of this place of attachment is a costa running from the medial condylus of the quadratum-squamosum joint to the processus pterygoideus; the dorsal and rostro-ventral borders practically coincide with the edges of the processus orbitalis.

Attachment in a musculous way also occurs to the medial surface of the dorsalwards projecting wing at the caudal end of the pterygoid. This wing occupies somewhat less than one third of the dorsal sharp edge of the pterygoid.

Attachment by means of an external aponeurosis. The aponeurosis (25) is no doubt an external aponeurosis with one wall (personal communication). It is a surface aponeurosis which spreads fan-like over the lateral surface of the muscle in a rostral direction. This aponeurosis is narrow at its base and occupies the edge of this dorsalwards projecting wing of the pterygoid.

2a. Surface of the area of attachment. The rostral part of the place of attachment, lying on the cerebral skull, is somewhat concave. The caudal part of the area of attachment, lying on the lateral surface of the tuba auditiva, is slightly convex.

2b. Surface of the area of attachment. The triangular place of musculous attachment on the quadratum is an excavation.

The place of musculous attachment on the wing of the pterygoid is somewhat concave; this is the case with both surfaces of the dorsalwards projecting wing of the pterygoid, as the edges are slightly thickened.

The edge to which aponeurosis (25) is attached is slightly thickened.

(H VIII) x. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus protractor quadrati et pterygoidei

(Bams, 1956, pp. 254-256; personal communication)

This muscle runs a) from the basis of the neurocranium, b) to the medial surface of the quadratum and the dorsal surface of the pterygoid.

1a. Musculous attachment. This occurs on the entire lateral surface of the basis of the neurocranium. The dorsal border of this area is not marked by a crista or anything of this kind on the surface of the skull; just dorsally of the area of attachment described lies the ventral border of the area of attachment of the musculus pseudotemporalis (both these muscles are entirely detached from each other). The rostral border of this area of attachment is the sharp ridge (j), to which a number of eye-muscles are attached by means of a medially situated aponeurosis. The ventro-medial border of this area of attachment over the whole length is the rather sharp edge of the basiphenoid where the flat horizontal part (where muscle attachments are entirely lacking) passes into the more vertical part; to the ventral surface of the rostrum sphenoidale no muscle fibres are attached; along its narrow lateral surface the area of attachment extends rostralwards. The caudal border of this area of attachment is the edge (aud), bearing the strip-like margin of cartilage to which the membrana tympani is attached.

1b. Musculous attachment. This occurs on the medial surface of the quadratum *viz.* mainly on its vertical part, the corpus ossis quadrati, but also on the broad base of the processus orbitalis.

Attachment in a musculous way in a small area on the caudal surface of the short, but high little crista (c.k.), lying just in front of the broadening of the cavitas glenoidalis of the pterygoid-quadratum-joint.

Attachment by means of an external aponeurosis. This occurs to the pterygoid by means of the aponeurosis (XVII), which is no doubt an external aponeurosis, having muscle fibres on its dorsal surface only (personal communication). This aponeurosis (XVII) is attached to a crista near the caudal end of the pterygoid; this little crista is short but high. The aponeurosis (XVII) on the pterygoid is directly continuous with aponeurosis (XV) on the quadratum, so that in fact these two form one aponeurosis.

Attachment to the quadratum occurs by means of the aponeurosis (XIII), which is no doubt an external aponeurosis with one wall, so a surface aponeurosis (personal communication). The position of this aponeurosis is found on the margin of the area of musculous attachment. This aponeurosis (XIII) is narrow and weak; it is attached at the base of the processus orbitalis of the quadratum.

Attachment to the quadratum also occurs by means of the aponeurosis (XV), which is no doubt an external aponeurosis with one wall, so a surface aponeurosis (personal communication). This aponeurosis lies on the margin of the area of musculous attachment. It is more strongly developed than aponeurosis (XIII) and is attached very far ventralwards to the quadratum, *viz.* on the medio-ventral edge.

2a. Surface of the area of attachment. No detailed description is given of the surface of the area of attachment, which is no doubt accidented.

2b. Surface of the area of attachment. The surface of the musculous attachment on the quadratum is perhaps partly concave, partly convex.

The surface of the musculous attachment on the caudal surface of the crista (c.k.) on the pterygoid is perhaps a little convex.

The crista to which the aponeurosis (XVII) is attached is small, short, but high.

The area of attachment of the aponeurosis (XIII) does not show any special differentiation for the attachment on the quadratum. The same is probably the case with the aponeurosis (XV).

3. Mutual course of the muscle fibres. The direction of the muscle fibres is widely divergent. The caudal muscle fibres run about latero-medialwards. The most caudal muscle fibres are even directed somewhat caudally towards the skull. Rostralwards this direction gradually changes into a direction which is at an angle of about 45° with the longitudinal axis of the head. So the muscle fibres on the rostral part run from caudo-lateral to rostro-medial.

The muscle fibres of the dorsal part of the muscle run more rostro-dorsally than the muscle fibres of the ventral part, which is directed nearly horizontally.

Heading IX: musculous — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading X: internal aponeurosis — musculous + internal aponeurosis

(H X) i. *Rana esculenta* L. (Salientia; Amphibia)

a. Musculus adductor mandibulae posterior longus

(Cool, 1953, pp. 237-239)

This muscle runs a) from the processus coronoideus of the lower jaw, b) to the prooticum, to the frontoparietale and to the synchondrosis prootico-occipitalis.

1a. Attachment by means of an internal aponeurosis. The short aponeurosis, attached to the processus coronoideus of the lower jaw is in my opinion probably an internal one. This area of attachment of the aponeurosis is found on the dorsal edge of the processus coronoideus which shows a long and narrow place of attachment.

1b. Musculous attachment. This occurs to the prooticum and to the frontoparietale.

Attachment by means of an internal aponeurosis. This very short aponeurosis, attached to the synchondrosis prootico-occipitalis, is in my opinion probably an internal aponeurosis. This area of attachment is a long oval area lying on the caudo-dorsal part of the skull.

2a. Surface of the area of attachment. No details are given.

2b. Surface of the area of attachment. In the first place this area contains the dorsal part of the deep excavation on the dorsal surface of the medio-dorsal part of the prooticum (the medial part of the surface of this excavation curves rather sharply dorsalwards, while the lateral part is horizontal); on this place of attachment the surface of the prooticum is osseous, except at its caudal surface in young specimens where cartilage covers the deeper bony prooticum. In the second place this area of attachment occupies the in my opinion probably plane surface of the lateral margin of the caudo-dorsal part of the fronto-parietale, running closely laterally from the short crista on the surface of the fronto-parietale and closely caudally from a costa on the surface of the fronto-parietale and on the prooticum. In the third place this area of attachment is found on the rostro-lateral half of the rounded ridge, formed by the synchondrosis prootico-occipitalis; here occurs a very short aponeurosis, in my opinion probably an internal aponeurosis, which can only be distinguished with difficulty.

(H X) ii. *Ondatra zibethica* (L.) (Rodentia; Mammalia)

a. Musculus digastricus

(VAN VENDELOO, 1953, pp. 268-270; personal communication)

This muscle is unpaired, showing the form of an Y. It runs a) from the most ventral part of the lower jaw, just caudally of the symphysis, ventro-rostrally, b) to the processus paroccipitalis, dorso-caudally.

1a. Attachment by means of an internal aponeurosis. The paired aponeurosis (Ad) is no doubt an internal aponeurosis (personal communication); the muscle fibres are slantingly attached to their ventral surfaces and to the most caudal parts of their dorsal surfaces. The breadth of this paired aponeurosis is about 3½ mm, laterally about 7 mm, medially about 2 mm. The paired aponeuroses are attached to the left and the right cristae (15).

1b. Musculous attachment. This occurs with a great number of muscle fibres to the top of the left and right processus paroccipitalis, so that the angle at which the muscle fibres stand on the top increases from rostral to caudal.

Attachment by means of an internal aponeurosis. The left and right aponeuroses (Bd) are no doubt internal aponeuroses (personal communication); the muscle fibres are slantingly attached to their ventral surfaces and to the most rostral parts of their dorsal surfaces. Caudally the width of these aponeuroses is about 1 mm, rostralwards they broaden to about 2½ mm and then diminish to 0. The left and the right aponeuroses (Bd) are attached to the rather sharp ridge on the rostral surface of the top of the left and right processus paroccipitalis.

2a. Surface of the area of attachment. The crista (15) is strong; it runs lateralwards from the caudal end of the symphysis; it is about 3 mm long and lies perpendicular to the longitudinal axis of the head.

2b. Surface of the area of attachment. The processus paroccipitalis sticks out ventralwards caudally of the bulla auditiva. The processus is a tuber to which the aponeurosis (Bd) is attached (p. 277). It is about 2 mm long and has a rather flat top, which is rostrally bordered by a rather sharp ridge.

3. Mutual course of the muscle fibres. This can be indicated by the parts of the muscle and by the attachment of the muscle fibres to the parts of the aponeuroses (Cd) and (C′d).

The muscle can be divided into four parts: a symmetrical left and right half, both halves consisting of a rostral and a caudal belly. The four parts are connected by the aponeuroses (Cd) and (C'd).

These two aponeuroses (Cd) and (C'd) are neither attached to one nor to both extreme areas of attachment of the muscle, so neither to the lower jaw nor to the processus paroccipitalis. This aponeurosis (C'd), however, is firmly connected with the os hyoideum. The most rostral point of the combined aponeurosis commences at about $12^1/_2$ mm caudally from the cristae (15). Its most caudal point does not reach the processus paroccipitalis.

The aponeurosis (Cd) is unpaired and consists of a left and a right half, which are firmly connected rostrally in the median. From the most rostral point both halves of the aponeurosis diverge caudalwards. We may distinguish a rostral and a caudal part of the aponeurosis (Cd). The limit between the rostral and the caudal part of each half is the line, where aponeurosis (C'd) is attached to aponeurosis (Cd), and which is directed perpendicularly to the longitudinal axis of the head.

The aponeurosis (C'd) is rostrally of the connection with the hyoideum unpaired. Rostrally it tapers to a point. Caudally of the connection with the os hyoideum two parts of the aponeurosis diverge caudalwards. These parts are connected along their medial borders with the rostral parts of the left and right halves of the aponeurosis (Cd), so that the aponeurosis (Cd) and the aponeurosis (C'd) can be considered as one aponeurosis. About 6 mm caudally of the connection with the os hyoideum both caudal parts of the aponeurosis (C'd) are firmly connected with the left and right halves of the aponeurosis (Cd) along the two transverse lines mentioned above.

The muscle fibres of the rostral bellies of the muscle are slantingly attached to the dorsal surface of the rostral part of each half of the aponeurosis (Cd). The muscle fibres of the caudal bellies are slantingly attached to the dorsal surface of the caudal part of each half of the aponeurosis (Cd).

The muscle fibres of the rostral bellies of the muscle are slantingly attached to the ventral surface of the aponeurosis (C'd). The muscle fibres of the caudal bellies of the muscle are slantingly attached to the dorsal surfaces of the caudal parts of the aponeurosis (C'd). To the dorsal surface of the rostral part of the aponeurosis (C'd) the muscle fibres of the tongue are attached.

Heading XI: internal aponeurosis — musculous + external aponeurosis

(H XI) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor mandibulae part A_2

(SARKAR, 1960, pp. 31-35, 101)

This muscle part runs a) from the medial surface of the lower jaw, b) to four different bones of the suspensorium (quadratum, praeoperculum, crista hyomandibularis, metapterygoid). The major part of the muscle is rectangular.

1a. Attachment by means of an internal aponeurosis. This internal aponeurosis (3) bifurcates near the place of attachment on the dentale. Each of the bifurcations of the rostral aponeurosis (3) is attached to a side of the anterior end of the dorsal costa (2), one to the upper and the other to the lower side (this dorsal costa (2) is the rim of the long dorsal process which together with the ventral process forms the forks of the dentale which is deeply forked behind). The angle of attachment of aponeurosis (3) to the lower jaw is about 30°.

1b. Musculous attachment. This occurs over almost the whole area on the suspensorium in the shape of a rectangle, covering the ventral half of the quadratum, the entire surface of the metapterygoid, the dorsal one-third of the praeoperculum and the ventral surface and the rostral ridge of the triangular crista hyomandibularis. A small area is found on the base of the temporal process; this portion of the muscle is very narrow.

Attachment by means of an external aponeurosis. This occurs to a small, thin aponeurosis, which in my opinion is perhaps an external surface aponeurosis, as it lies on the lower surface of the small remaining bundles of muscle fibres which run straight, dorso-caudally to be attached to the base of the temporal process.

Attachment in an aponeurotic way by means of the "superficial" aponeurosis (4); in my opinion this is an external surface aponeurosis. This aponeurosis is attached to the rostral ridge of the crista hyomandibularis. Near its place of attachment this aponeurosis (4) is fused with the aponeurosis of the dorsal part of the muscle A1mβ.

2a. Surface of the area of attachment. This area of each bifurcation of the rostral aponeurosis (3) is narrow and rectangular.

3. Mutual course of the muscle fibres. In the bigger portion of the muscle, which has its attachment to the praeoperculum, the anterior muscle fibres are directed caudo-ventrally from the rostral aponeurosis at an angle greater than 90°, while the posterior muscle fibres of this praeopercular part of the muscle are directed more caudally and start from the caudal part of the rostral aponeurosis at an obtuse angle in relation to the anterior muscle fibres. Dorsal to this praeopercular part, another small portion of the muscle runs dorsally from the extreme caudal end of the rostral aponeurosis (3) towards the entire ventral surface of the crista hyomandibularis. The remaining bundles of muscle fibres of this portion of the muscle run straight, dorso-caudally to be attached to the base of the temporal process.

The muscle fibres attached to the surface aponeurosis (4), attached to the crista hyomandibularis, run ventrally and meet the dorsal surface of the rostral aponeurosis (3) of the muscle.

(H XI) ii. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus adductor mandibulae internus pseudotemporalis superficialis

(Bams, 1956, pp. 252-254; personal communication)

This muscle runs a) from the lower jaw on one side, b) to the region on the neurocranium caudally of the orbita; the muscle lies with a flattened rostral side against a gland filling the space between the rim of the orbita and the eye, on the other side. This muscle which is absolutely independent of the musculus adductor mandibulae externus et posterior, a complex muscle, and also of other adjacent muscles, is situated medially of the above-mentioned complex muscle and occupies the entire remaining space between orbita and processus temporalis and the wall of the neurocranium.

1a. Attachment by means of an internal aponeurosis. This aponeurosis (XI) is no doubt an internal aponeurosis (personal communication); on its lateral surface it carries muscle fibres running to the medial surface of aponeurosis (VI) and on its medial surface it carries muscle fibres running to the lateral side of aponeurosis (XVI). On the other hand this aponeurosis (XI) covers the lateral and rostral surfaces of the muscle belly. This aponeurosis (XI) is strongly developed; the cause of its strength is the fact that all the muscle fibres pass into it. The aponeurosis (XI) is very much narrowed at its ventral end and so it has in fact become a tendon at this place. Because of the almost parallel direction of the wall of the skull at this place, the muscle fibres are able to attach as far as the lowest point into this aponeurosis (XI). Only the last few mm, where the aponeurosis has the character of a tendon, are free from muscle fibres (thus we probably have to deal with a "stalk"). The aponeurosis is attached on and round the knob (R) on the medial surface of the lower jaw; the aponeurosis is perpendicularly attached to the longitudinal axis of the lower jaw, when the bill is closed.

1b. Musculous attachment. This occurs to an area of attachment on the wall of the neurocranium which is bordered on the dorsal side by the crista postorbitalis; in a ventral direction the area of attachment on the neurocranium is restricted; it cannot extend farther ventralwards because it abuts on the area of attachment of the musculus protractor quadrati et pterygoidei. The crista postorbitalis is constituted by the edge of the part which is not excavated; this edge is very sharp.

Attachment by means of an external aponeurosis. The surface aponeurosis (VI) is no doubt an external aponeurosis with one wall (personal communication); it carries the muscle fibres on its medial surface. The aponeurosis (VI) is attached to the crista postorbitalis and ends just in front of the processus temporalis. This aponeurosis (VI) is attached to the same crista as aponeurosis (IV) of the musculus adductor mandibulae externus and both aponeuroses run in exactly the same direction. It is impossible to separate the two parts of the fused aponeuroses (IV) and (VI) from each other. The part of the fused aponeuroses (IV) and (VI) belonging to the musculus adductor mandibulae internus pseudotemporalis superficialis, however, is not considerable. All the muscle fibres inserting *in* this aponeurosis (VI), are attached *to* aponeurosis (XI). They do not enter *into* it, as is generally the case at the transition of the muscle fibre into the corresponding aponeurosis, but are fixed *upon* it, probably without forming a continuous fibre to the point of action, as is the case when muscle fibres pass into their own aponeurosis. The connection also is not nearly so firm. These fibres constitute an extra strain upon the aponeurosis concerned; accordingly a strong development of this kind of attachment, which occurs in other muscles as well, has never been observed in species of birds investigated in the Leyden laboratory. Undoubtedly they are secondary fibres.

Another attachment by means of an external aponeurosis occurs with aponeurosis (XVI). This is no doubt an external aponeurosis being a surface aponeurosis with one wall (personal communication), judging by the position of this aponeurosis at the border of the area of musculous attachment; this aponeurosis carries muscle fibres on its lateral side. This aponeurosis (XVI) sometimes occurs as a narrow weak aponeurosis on the medial side of the muscle, quite ventrally. The number of muscle fibres attached to aponeurosis (XVI) is not great, and there would be no room for more on the surface of the neurocranium, in view of the space available for the musculus adductor mandibulae internus pseudotemporalis superficialis, which space is restricted by the musculus protractor quadrati et pterygoidei.

2a. Surface of the area of attachment. The shape of the knob (R) on the medial surface of the lower jaw, on which and round which the tendon-like end of the aponeurosis (XI) is attached, is not described in detail.

2b. Surface of the area of attachment. This area of musculous attachment is somewhat excavated. The crista to which aponeurosis (VI) is attached is the same crista as that of aponeurosis (IV).

The place of attachment of the aponeurosis (XVI) on the wall of the skull is in no way visibly differentiated.

3. Mutual course of the muscle fibres. This is determined by the shape of the muscle: a flattened pyramid, the top of which is represented by the tendon of aponeurosis (XI), while the obliquely truncated base is the place of attachment on the neurocranium. In the second place the course of the muscle fibres is determined by the fact that the aponeuroses (VI) and (XVI) on the one side and the aponeurosis (XI) on the other side are placed alternately.

Heading XII: internal aponeurosis — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XIII: external aponeurosis — musculous + internal aponeurosis

(H XIII) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor maxillae part $A_1m\beta$

(SARKAR, 1960, pp. 40-42)

This muscle runs a) from the rostral rim of the crista hyomandibularis, b) to the caudal surface of the maxilla and to the big aponeurosis (3) of the rostro-dorsal part of muscle A2, which is attached to the lower jaw. This muscle is big; it is very thick anteriorly, but at about the middle of its length it abruptly becomes very thin and remains so to the aponeurosis.

1a. Attachment by means of an external aponeurosis. This occurs with the very prominent aponeurosis (14), which in my opinion is perhaps an external aponeurosis, showing a double-sided wall. This supposition may in my opinion be based on the fact, that there is not only a dorsal part and a ventral part of the aponeurosis (14), but also that this ventral part of the aponeurosis has a greater rostral extension on the lateral surface of the muscle than on the medial surface, so that the length of the medial fibres is greater than that of the lateral fibres. Muscle fibres are attached to the ventro-lateral surface of the thin, broad, almost vertical caudal aponeurosis (14). In the middle region this aponeurosis (14) can be separated into two parts. The dorsal part is curved and bears rostral muscle fibres. The ventral part is broad and nearly straight and bears rostral muscle fibres. Caudally these two separated parts of the aponeurosis are united and attached to a long narrow area of attachment on the rostral rim of the crista hyomandibularis. A short, thin and flat aponeurosis (15) connects, posteriorly, the ventral part of the aponeurosis (14) with, anteriorly, the dorsal aponeurosis (4) of muscle A2.

1b. Musculous attachment. This occurs with most of the anterior part of the muscle to the ventral half of the caudal surface of the maxilla. The area of attachment for the major part of the muscle is broad and flat and occupies the less grooved caudal surface of the ventral half of the maxilla.

Musculous attachment also occurs with rostral muscle fibres from the dorsal part of the aponeurosis (14); they are attached in part to the caudal surface of the maxilla and in part to the rostro-dorsal region of the muscle A2. Rostral muscle fibres from the ventral part are attached to the remaining portion of the caudal surface of the maxilla.

Attachment by means of an internal aponeurosis. This occurs by means of the aponeurosis (3). To this big rostral aponeurosis (3) of muscle A2 a small, long and thin portion of the muscle $A1m\beta$ is attached. This aponeurosis (3) is attached to the medial surface of the lower jaw.

2a. Surface of the area of attachment. No detailed description is given.

2b. Surface of the area of attachment. This surface, lying ventrally to the groove, is rough (p. 100).

3. Mutual course of the muscle fibres. The angle of attachment of the

muscle fibres with the maxilla varies from 45° to 90°; the thin portion makes an angle of about 45° with the aponeurosis (3).

Most of the lateral muscle fibres from the ventral part of the aponeurosis (14) run in a straight line rostrally, while a few ventral bundles bend a little downwards and are attached to the caudal surface of the maxilla.

(H XIII) ii. *Phasianus colchicus* L. (Galli; Aves)

a. Small muscle bundle connecting the musculus adductor mandibulae externus with the musculus adductor mandibulae posterior

(Fuchs, 1954, pp. 458-459; personal communication; Burggraaf & Fuchs, 1955, p. 98)

This small muscle bundle connecting the two mentioned muscles occurs in a number of cases; it runs a) from the lower jaw in a medio-caudo-dorsal direction, b) to the quadratum.

1a. Attachment by means of an external aponeurosis. This is found on the lower jaw either to a very small area near crista (7′) on the medial surface of aponeurosis (7), which for the rest is a surface aponeurosis (in that case the aponeurosis (7) may be considered an internal aponeurosis; personal communication), or to the medial surface of a separate, very small surface aponeurosis (7′) which may sometimes have the appearance of a tendon.

1b. Musculous attachment. This occurs on the area on the lateral surface of the quadratum dorsally of crista (12).

Attachment by means of an internal aponeurosis. On this aponeurosis (12) the muscle fibres of the musculus adductor mandibulae posterior are attached on the medial surface; muscle fibres of this small muscle bundle are attached to the lateral surface of this aponeurosis, only in the immediate vicinity of crista (12) (in cases of the presence of this small muscle bundle, therefore, this aponeurosis is an internal one; personal communication).

2a. Surface of the area of attachment. The aponeurosis (7′) is attached to crista (7′) close by the side of aponeurosis (7).

Heading XIV: external aponeurosis — musculous + external aponeurosis

(H XIV) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor maxillae part A1α

(Sarkar, 1960, pp. 36-38, 100)

This triangular muscle part runs a) from the processus inferior of the maxilla, b) to the praeoperculum, the crista hyomandibularis and the temporal process.

1a. Attachment by means of an external aponeurosis. In my opinion the aponeurosis (6), which is a surface aponeurosis, is no doubt an external aponeurosis. This strong aponeurosis (6) runs backwards, becomes broader and extends halfway along the length of the muscle. The aponeurosis is concave on its dorsal surface and is dorsally covered by a similar curved ventral portion of the muscle A1mβ. This aponeurosis (6) is attached to the processus inferior of the maxilla at an angle of 90°; the area of attachment is narrow and triangular. There are a few fibrous attachments of muscle A1mβ running caudo-dorsally from the anterior part of this aponeurosis. These fibres make an angle of attachment of approximately 45° with the aponeurosis (6).

1b. Musculous attachment. This occurs with the ventral posterior part of the muscle to the middle one-third of the lateral surface of the praeoperculum. The ventral part of the muscle includes the posteriorly diverging fibres from the rostral aponeurosis (6), which are attached either to both sides of the fine costae in the middle part of the praeoperculum, or to the connective tissue covering the rim of the same bone.

Attachment by means of an external aponeurosis. The aponeurosis (7) is in my opinion perhaps an external aponeurosis. It attaches to the dorsal posterior part of the muscle. This aponeurosis (7) is attached to the basal part of the temporal process. During its rostral course it is connected to the lateral rim of the crista hyomandibularis. The aponeurosis (7) is broader anteriorly, but gradually narrows backwards medially to the dorsal process of the operculum.

2a. Surface of the area of attachment. No detailed description is given.

2b. Surface of the area of attachment. This area on the basal part of the temporal process occupies a small region on the rostro-ventral surface of the process, having the shape of a rectangle whose dorsal border-line is formed by a crest, the other borders not forming any notable structure.

3. Mutual course of the muscle fibres. The fibres from the anterior, broader surface of the aponeurosis (7) are directed a little ventrally and meet the posterior half of the rostral aponeurosis (6) at an angle greater than 90°. The deeper medial fibres of this part join the same aponeurosis almost at the same place, but medially. A few ventral bundles of fibres of this part join the rostral aponeurosis (6) either in a straight line or else are curved ventrally to meet it.

The superficial lateral fibres of that part of the muscle containing the posteriorly diverging fibres from the rostral aponeurosis, run halfway in an almost straight line towards the aponeurosis (6), but the similar lateral fibres of the ventral part make an acute angle with it.

(H XIV) ii. *Columba palumbus palumbus* L. (Columbae; Aves)

a. Musculus adductor mandibulae externus superficialis

(ROOTH, 1953, pp. 252-253; personal communication)

This muscle runs a) from a spina on the suprangulare of the lower jaw caudo-dorsally, b) to the squamosum.

1a. Attachment by means of an external aponeurosis. This aponeurosis (9) is no doubt an external surface aponeurosis (personal communication); the muscle fibres are attached to the dorso-rostral side of aponeurosis (9). The aponeurosis (9) is attached to a spina (9) on the suprangulare. This spina (9) lies at the caudal end of the edge separating the inner plane from the lateral one of the high and narrow rostral part of the lower jaw. This aponeurosis (9) is broadest at the dorso-caudal end and here many muscle fibres find their attachment on it. Ventro-rostrally the aponeurosis becomes narrower and narrower and the number of muscle fibres attached to it diminishes. No muscle fibres are attached to the most rostro-ventral part of the aponeurosis, assuming a tendinous appearance near the place of insertion of the muscle (in my opinion this is not a "tendon", but a "stalk").

1b. Musculous attachment. This occurs on an area of the squamosum with the shape of a crescent or yoke, the outer circumference of which is defined by a crista (3).

Attachment by means of an external aponeurosis. This occurs by the aponeurosis (3). This is no doubt an external superficial aponeurosis (personal communication); this aponeurosis covers the dorso-lateral surface of the muscle and is attached to crista (3) on the squamosum.

2a. Surface of the area of attachment. The spina (9) has no doubt the shape of a spina.

2b. Surface of the area of attachment. The crescent or yoke has a convex side which is directed dorso-caudally. The crista (3) has the shape of a crista.

3. Mutual course of the muscle fibres. They run in a caudo-dorsal direction from the lower jaw to the squamosum and diverge in a bundle running from the squamosum to the lower jaw.

(H XIV) iii. *Ardea cinerea* (L.) (Gressores; Aves)

a. Musculus adductor mandibulae internus pseudotemporalis superficialis

(Bas, 1955, p. 102; personal communication)

This muscle runs a) from the medial surface of the lower jaw in a dorsal direction, b) to the surface of the cerebral skull just caudally of the orbita.

1a. Attachment by means of an external aponeurosis. This tendon (9) is no doubt an external aponeurosis with one wall (personal communication); at about one third of the length of the muscle from its dorsal end the aponeurosis becomes visible on the lateral surface; ventralwards it becomes stronger and stronger and a little farther than halfway the length of the muscle it passes into the tendon.

1b. Musculous attachment. This occurs on the cerebral skull to an area which has about the shape of a square with rounded angles, which lies just caudally of the orbita; the dorsal border runs at a short distance ventrally of crista (2); the caudal border runs at a short distance rostrally along the rostro-dorsal half of crista (4); the rostral border is a slight crista which runs from the processus postorbitalis in a ventro-medial direction on the surface of the orbita (to this crista no aponeurosis is attached).

Attachment by means of an external aponeurosis. The aponeurosis (12) is no doubt an external aponeurosis with one wall (personal communication); its place of attachment lies in the ventral border of the area of musculous attachment just mentioned; this aponeurosis (12) is very small and sometimes absent.

2a. Surface of the area of attachment. The tendon-like aponeurosis (9) is attached to spina (9), lying on the medial surface of the lower jaw, halfway up its height and somewhat rostrally of spina (7), which occupies the medial edge of the dorsal surface of the jaw.

2b. Surface of the area of attachment. The area of musculous attachment is slightly convex. The aponeurosis (12), if present, is attached to the spina (12) which is small or absent.

3. Mutual course of the muscle fibres. The muscle fibres diverge from the area of attachment on the lower jaw to that on the cerebral skull.

(H XIV) iv. *Ondatra zibethica* (L.) (Rodentia; Mammalia)

a. Musculus masseter I

(Van Vendeloo, 1953, pp. 120-122; personal communication)

This muscle runs a) from the rostral part of the maxillare, b) to the processus angularis of the lower jaw.

1a. Attachment by means of an external aponeurosis. This aponeurosis (B) is no doubt an external aponeurosis with one wall (personal communication). It is a surface aponeurosis, judging from the fact that this triangular aponeurosis covers laterally the rostral half of the muscle and from the fact that medially the muscle fibres are attached slantingly to the medial surface of this aponeurosis. This aponeurosis (B) is attached to the rostral part of the maxillare.

1b. Musculous attachment. This occurs to the bone of the lower jaw on the flat surface of the ventral plane of the processus angularis between the lateral crista (1) and the medial crista (1'); near crista (1') the muscle fibres are perpendicular to the bone.

Attachment by means of an external aponeurosis. This aponeurosis (A) is very probably an external aponeurosis with one wall (personal communication). It is probably a surface aponeurosis and lies on the medial side of the muscle. The aponeurosis (A) is very short. It is attached to crista (1).

2a. Surface of the area of attachment. The aponeurosis (B) is attached to an oval fossa (1), lying in the rostral part of the maxillare; this fossa is about 2 mm long and about 1$^1/_2$ mm high. On the bottom of this fossa (1) lies a "field" (p. 276).

2b. Surface of the area of attachment. This area is a flat surface, which is about 1 mm broad and which is bordered on the lateral border by the crista (1) and on the medial border by the crista (1').

The crista (1) is not described in detail.

3. Mutual course of the muscle fibres. The muscle is flat. It is broadened caudalwards and rostralwards it tapers to a point. As to the caudal area of attachment, only laterally the muscle fibres are attached slantingly to the aponeurosis (A). Near crista (1') the muscle fibres are perpendicular to the bone of the lower jaw.

Heading XV: external aponeurosis — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XVI: musculous — musculous + internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned

Heading XVII: internal aponeurosis — musculous + internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XVIII: external aponeurosis — musculous + internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XIX: musculous + internal aponeurosis — musculous + internal aponeurosis

(H XIX) i. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus adductor mandibulae posterior

(Davids, 1952, pp. 90-92)

Together with the musculus pseudotemporalis profundus and the musculus adductor mandibulae externus profundus it forms a muscular complex which runs a) from the lateral side of the quadratum, b) to the lateral surface of the lower jaw behind the processus coronoideus. The musculus adductor mandibulae posterior is the largest muscle of the three; it lies in the midst; the caudo-ventral part of this muscle has a far lateral position.

1a. Musculous attachment. This occurs to an area on the processus orbitalis quadrati, which lies on the caudal side of tuber (12) and which extends from the dorsal border as far as the ventral border of the processus orbitalis quadrati. This area is passed through by a costa (14) which extends from tuber (12) in a caudo-ventral direction as far as the corpus quadrati. The caudal border of this area of musculous attachment is not indicated on the osseous surface. Very probably muscle fibres are also attached on the lateral surface of the portio posterior pterygoidei.

Attachment by means of an internal aponeurosis. The aponeurosis (12) is in my opinion probably an internal aponeurosis, as this aponeurosis (12) is attached to a tuber (12), which lies on the lateral surface of the quadratum.

1b. Musculous attachment. The majority of the muscle fibres show a musculous attachment to an area of attachment, which ends rostrally at the processus coronoideus and at the area of attachment of the musculus pseudotemporalis profundus; this first mentioned area ends dorsally at the dorsal border of the lower jaw; it ends caudally at the lateral cavity of the articulatio quadrato-mandibulare and at the processus mandibularis externus and ventralwards it is indicated by a tender costa which extends from tuber (15) rostro-ventralwards and which approaches very near to the ventral border of the lower jaw at the height of the processus coronoideus.

Attachment by means of an internal aponeurosis. The most caudal muscle fibres are attached by means of the aponeurosis (15) which in my opinion is probably an internal aponeurosis as it is probably also for the musculus adductor mandibulae externus profundus.

2a. Surface of the area of attachment. This surface for musculous attachment is perhaps a little curved; it shows a costa on its surface. At the height of costa (14) the surface of attachment is concave. The tuber (12) has the shape of a tuber.

2b. Surface of the area of attachment. This surface for musculous attachment is a convex area.

3. Mutual course of the muscle fibres. At the place of attachment to

the aponeurosis (12) this course gradually alters from the course of the muscle fibres of the musculus pseudotemporalis profundus in front to the course of the muscle fibres of the musculus adductor mandibulae externus profundus behind. This agrees with the fan-shaped structure of aponeurosis (12).

The most caudal muscle fibres show a very sharp angle with the concave surface of attachment on the quadratum at the height of costa (14); they run to aponeurosis (15) on the lower jaw.

(H XIX) ii. *Ondatra zibethica* (L.) (Rodentia; Mammalia)

a. Musculus masseter III

(Van Vendeloo, 1953, pp. 126-127; personal communication)

This muscle runs a) from the ventral surface of the zygomatic arch, b) to the lateral surface of the lower jaw. This 3rd part of the musculus masseter cannot be sharply separated from the musculus masseter II; rostrally the parts II and III are connected by the aponeuroses (F) — (F′).

1a. Musculous attachment. This occurs to the ventral plane of the zygomatic arch in the region of the pillar (P); this pillar supports the rostral half of the zygomatic arch and its rostral end is attached dorsally to the conical rostral part of the skull. Caudally of this region a part of the muscle is situated caudo-medially from the pillar (P) and runs rostralwards. The fibres of this muscle part cover the flat upper surface of the pillar and run to the fossa (2) to which part of these muscle fibres is musculously attached. This fossa (2) is situated on the maxillare near the rostral end of the zygomatic arch.

Attachment in a musculous way to the slightly concave medial surface of the zygomatic arch between two points in the caudal part of the ventral surface of the zygomatic arch, caudally of the pillar (P), where these fibres are musculously attached.

Attachment by means of an internal aponeurosis. The aponeurosis (G) is an internal aponeurosis (personal communication). To both surfaces of the aponeurosis (G) muscle fibres are slantingly attached. The aponeurosis (G) is attached to the cristae (10) and (4) from a point near the rostral end to a point near the caudal end of the ventral surface of the zygomatic arch. The aponeurosis has a maximal length of 7 mm, diminishing rostralwards and caudalwards to 0.

Attachment by means of other internal aponeuroses occurs by two very small and thin internal aponeuroses. The muscle fibres are attached to both surfaces of these very small and thin aponeuroses. One of these aponeuroses is attached to a line about 1 mm ventrally of the most dorsal part of the crista (3), near the most rostral end of the ventral margin of the zygomatic arch. The other internal aponeurosis is attached to the rostral part of the crista (6), lying on the rostral and ventral border of the fossa (2).

1b. Musculous attachment. This occurs to the lateral surface of the lower jaw between the fossa (3) and the crista (9) (see also pp. 271-272). The fossa (3) runs along the lower jaw from dorsal to ventral; the crista (9) runs in a horizontal direction and lies ventralwards.

Attachment by means of an internal aponeurosis. This is the case with the aponeurosis (F′), which is an internal aponeurosis (personal communication); muscle fibres are slantingly attached to the whole lateral surface of this aponeurosis and here and there in a small number to the medial surface of this aponeurosis. Aponeurosis (F′) is attached to the ventral part of the fossa (3). The rostral edge of this aponeurosis is firmly connected over its whole length with the rostral edge of the aponeurosis (F). — The length of the aponeurosis (F′) is rather varying, especially because of a small slip of about

6 mm long, sticking out and lying medially over the pillar (P). Its maximal length is about 15 mm.

Another attachment by means of an internal aponeurosis is found with the aponeurosis (F). The dorsal part of the aponeurosis (F) is an internal aponeurosis, the ventral part of the aponeurosis (F) is an external aponeurosis (personal communication). The muscle fibres of the muscle under discussion, however, are slantingly attached to the medial surface of this aponeurosis, *i.e.* to the most ventral part (3 mm long) of this surface.

2a. Surface of the area of attachment. The fossa (2) is about 1/2 cm large in a dorso-ventral direction, its size in rostro-caudal direction cannot be determined, as it is confluent with the orbita medial from the pillar (P). Its rostral and ventral border is formed by a crista (6).

The crista (6) lies on the rostral and ventral border of the fossa (2).

The crista (4) runs parallel to the crista (3), which forms the ventral surface of the zygomatic arch; the crista (4) runs in the middle part of this ventral surface.

The crista (10) runs parallel to the crista (3), which forms the ventral surface of the zygomatic arch; in the rostral part the crista (10) runs on this ventral surface.

The line about 1 mm ventrally of the most dorsal part of the crista (3) near the most rostral end of the ventral margin of the zygomatic arch, is not described in detail.

2b. Surface of the area of attachment. That for musculous attachment on the lateral surface of the lower jaw is not described in detail.

The ventral part of the fossa (3) will no doubt have the shape of a fossa. To it aponeurosis (F′) is attached, the rostral edge of this aponeurosis (F′) being firmly connected over its whole length with the rostral edge of the aponeurosis (F).

b. Musculus pterygoideus

(Van Vendeloo, 1953, pp. 270-272; personal communication)

This muscle runs a) from the medial surface of the processus angularis of the lower jaw, b) to the ventral surface of the cerebral skull, caudally of the third molar of the upper jaw.

1a. Musculous attachment. Attachment in a musculous way to the medial surface of the processus angularis of the lower jaw between the crista (1′) and the fossa (4) and rostro-dorsally of the fossa (4) to a region of about 3 mm broad and about 6 mm long.

Attachment by means of an internal aponeurosis. These are the internal aponeuroses (Ap) and (Bp) (personal communication). To the medial surface of (Ap) a small number of muscle fibres are slantingly attached, to its lateral surface a great number of muscle fibres are slantingly attached. The aponeurosis (Ap) is about 11 mm wide, its length is rostrally about 1 mm, caudally about 2 mm. Its form is irregular. Its maximal length is about 4 1/2 mm. The aponeurosis (Ap) is attached to the crista (1′), lying on the ventro-caudal border of the medial surface of the processus angularis.

As to the attachment to the internal aponeurosis (Bp) we mention that the muscle fibres are slantingly attached to both surfaces of the strong aponeurosis which is situated more laterally in the muscle. The aponeurosis is about 7 mm wide, rostrally it is about 10 mm, caudally about 6 1/2 mm long; its maximal length is about 13 1/2 mm. The aponeurosis (Bp) is attached to the fossa (4). This fossa (4) runs parallel with the crista (1′) at a distance between the crista (1′) and the fossa (4) of about 1 mm on the medial plane of the processus angularis from a point, about 1 mm caudally of the point (pA′) to a point about 2 mm ventrally of the top of the processus angularis.

1b. Musculous attachment. This occurs to the bottom of the fossa (which is enclosed by the cristae (16) and (17) and by the bulla auditiva) and to the lateral surface of the high crista (16) and the medial surface of the high crista (17).

Attachment by means of an internal aponeurosis. To both surfaces of this aponeurosis (Cp) the muscle fibres are slantingly attached. This aponeurosis is about 4 mm wide, its length ranges from about 3 to 7$^1/_2$ mm. It is directed ventralwards medially of the aponeurosis (Bp). The aponeurosis (Cp) is attached to crista (16).

As to the attachment by means of the internal aponeurosis (C'p) we mention that to both surfaces muscle fibres are slantingly attached. The aponeurosis (C'p) is about 8 mm wide, its length ranges from about 1 to 4 mm. It runs ventralwards laterally of the aponeurosis (Bp). Rostrally the aponeuroses (Cp) and (C'p) are firmly connected, so that they can be considered as one aponeurosis. The aponeurosis (C'p) is attached to the crista (17).

2a. Surface of the area of attachment. The medial surface of the triangular processus angularis of the lower jaw is slightly concave.

The crista (1') is sharp; it runs from the point (pA') to the top; the point (pA') lies on the ventral surface of the lower jaw, about 1$^1/_2$ cm dorso-caudally of the crista (15).

The fossa (4) is like a very shallow furrow.

2b. Surface of the area of attachment. The bottom of the fossa is flat. From this bottom the wall of the bulla auditiva slants ventro-caudalwards, about 5 mm caudally of the rostral end of the horseshoe-shaped crista.

The crista (16) forms the medial part of the horseshoe-shaped crista and the medial border of the fossa; this crista is about 6 mm high and about 7$^1/_2$ mm long.

The crista (17) is the rostral and lateral part of the horseshoe-shaped crista and the rostral and lateral border of the fossa; this crista is rostrally about 6 mm, caudally about 2 mm high.

Heading XX: musculous + external aponeurosis — musculous + external aponeurosis

(H XX) i. *Raja batis* L. (Rajiformes; Pisces)

a. Muscle in the floor of the buccal cavity

(Gottenbos, 1956, p. 553)

This muscle runs a) from the right hyomandibulare, b) to the left hyomandibulare, if we take this muscle on the right side of the head and on the left side of the head as one unpaired muscle.

1a, 1b. Musculous attachment. The attachment to the right and to the left hyomandibulare is partly musculous.

Attachment by means of an external aponeurosis. This partial attachment occurs to right and left hyomandibulare.

2a, 2b. Surface of the area of attachment. The area of the musculous attachment lies on a slightly concave caudo-ventral facet near the little knob on the hyomandibulare.

Just rostrally to the place of this musculous attachment lies that of the external aponeurosis (as such acts the aponeurosis of the musculus depressor hyomandibularis).

3. Mutual course of the muscle fibres. The course of the fibres of this flat muscle, running medialwards to medio-caudalwards, is about parallel.

4, 5. The carrying surfaces of the two areas of attachment apparently lie parallel to each other and opposite each other.

(H XX) ii. *Vipera berus* (L.) (Serpentes; Reptilia)

a. Musculus adductor mandibulae externus superficialis

(DULLEMEIJER, 1956a, pp. 14-16; 1956b, pp. 400-402; personal communication)

This muscle runs a) from the cerebral skull behind the orbita, b) to the lower jaw.

1a. Musculous attachment. This is the attachment of the first part of the muscle to the cerebral skull behind the orbita. The second part of this muscle shows a musculous attachment to the connective tissue around the glandula venenata.

Attachment by means of an external aponeurosis. Sometimes the attachment to the smooth line on the dorsal border of the area of attachment takes place by means of a plate-like external aponeurosis (personal communication); this aponeurosis is interrupted, *i.e.* it shows deep incisions of the free margin.

1b. Musculous attachment. In a few cases some of the medial fibres of the first part of this muscle show a musculous attachment on the lower jaw. In some cases there is a musculous attachment between the separated medial and lateral plate of the aponeurosis on the dorsal margin of the lower jaw.

Attachment by means of an external aponeurosis. This is the case with the aponeurosis of the first part of the muscle (personal communication). This aponeurosis is plate-like and bears the muscle fibres on its medial surface. It is attached to a line on the lateral surface of the lower jaw. The second part of this muscle is attached by means of a V-shaped gutter-like external aponeurosis to a line on the dorsal margin of the lower jaw.

2a. Surface of the area of attachment. This area on the cerebral skull, showing a somewhat triangular shape, lies on a rounded part of the cerebral skull, facing laterally.

2b. Surface of the area of attachment. This area on the lower jaw is quite narrow; the aponeurosis of the first part of the muscle is tangentially attached to the lower jaw (see also 1956a, pp. 71, 106; 1956b, pp. 457, 492).

3. Mutual course of the muscle fibres. This course near the area of implantation of the first part of this muscle on the cerebral skull is such that it occurs with acute angles. The muscle fibres of the second part, when starting from the glandula venenata, run into a caudal direction, turn around the caudal end of the gland and are further on directed rostro-ventrally. The course of the muscle fibres of the first part of the muscle, attached to the aponeurosis on the lower jaw, is such that they diverge a little dorsalwards. The muscle fibres of the second part of the muscle converge a little near the lower jaw.

(H XX) iii. *Phalacrocorax carbo sinensis* (Shaw & Nodder) (Steganopodes; Aves)

a. Musculus depressor mandibulae

(DULLEMEIJER, 1951, pp. 402-404)

This muscle runs a) from the squamosum behind the quadratum-squamosum joint, b) to the lower jaw, behind the quadratum-articulare joint.

1a. Musculous attachment. This occurs with the lateral part of the squamosum. The attachment to the ventral part of the squamosum, which lies close behind the joint, is musculous; the area of attachment is medially bordered by a half-round slight rise like a truncated cone, bearing the attachment of a ligamentum on its top.

Attachment by means of an external aponeurosis. The attachment to the top of the crista which surrounds the area of musculous attachment entirely, occurs by means of surface aponeuroses; these aponeuroses are in my opinion external aponeuroses with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeuroses.

1b. Musculous attachment. This occurs to the almost vertical area of attachment, lying latero-caudally of the most lateral cavity of the joint, at all events to the lower portion. The upper portion of this part is occupied by loose tissue between muscle and bone. To the most dorsal margin of this area, *i.e.* the lateral border of the principal joint-cavity, a few muscle fibres are attached, which run parallel to those of the vertical part. A vertical costa on the back of the joint divides incompletely the vertical area of musculous attachment from the horizontal area of attachment lying entirely caudally of the joint. The attachment to the horizontal area of attachment is musculous.

Attachment by means of an external aponeurosis. The attachment to the bevelled little crista, which occurs on the lower side of this vertical area of musculous attachment and which slowly passes into the convex jaw-part, occurs by means of a small aponeurosis. As in so many cases in this paper, the character of this aponeurosis is not indicated. In a general remark at the end of this paper (p. 404), however, it is said that "aponeuroses lie chiefly on the surface of the muscle". This means that in all cases we have to deal with external aponeuroses, showing a total loss of one of the walls, the muscle fibres starting from one plane of the aponeuroses; in one muscle only part of the aponeurosis penetrates into the muscle. Attachment to the little caudal crista at the caudal limit of this horizontal area of attachment, occurs by means of an aponeurosis, in my opinion probably an external aponeurosis, showing a total loss of one of the walls. Running over the costa, at the most lateral limit of this horizontal area of attachment, a surface aponeurosis passes into the periost. Rostralwards this costa becomes sharper and changes into a spina, to which a very narrow aponeurosis (M) is attached, which is a surface aponeurosis, that is an external aponeurosis with a total loss of one of the walls. To the top of a crista, which medially limits a triangular area we find an aponeurotic attachment. To its medial portion the triangular area shows the attachment of a ligamentum and in its centre a foramen for the entry of a small blood-vessel and a nerve.

2a. Surface of the area of attachment. The area of musculous attachment on the lateral part of the squamosum has an irregular shape and is almost flattened. The surrounding or limiting crista is very low. The area of musculous attachment to the ventral part of the squamosum is somewhat concave.

2b. Surface of the area of attachment. The area of musculous attachment on the vertical area on the lower jaw is irregularly quadrangular and a little concave. The area of musculous attachment on the horizontal area on the lower jaw is an irregularly quadrangular slight fossa. The spina at the end of the costa may be a little rough or blunt on its top. No detailed remarks are made on the bevelled little crista, the caudal crista, the medial crista and the costa.

3. Mutual course of the muscle fibres. The muscle is divided into two parts: a lateral and a caudal one. Only in the centre of the muscle the fibres cross each other a little (see also DULLEMEIJER, 1952, p. 95). There are only a small number of fibres that are attached to the area of attachment at one end of the muscle described now, but not to the area at the other end. This is the case with some fibres attached to the aponeurosis (M) on the spina on the lower jaw, but at the other end to the connective tissue plate of the musculus adductor externus. The muscle fibres running to the lateral

part on the squamosum are directed a little caudalwards; they arise from the lateral part on the lower jaw and from the surface aponeurosis; they run to the lateral part of the aponeurosis on the squamosum, to the squamosum itself and to the aponeurosis of the musculus adductor externus. The muscle fibres running to the medial part of the squamosum are directed a little rostralwards; they arise from the caudal part of the lower jaw. The muscle fibres arising from the surface aponeurosis running over the costa, belong to the lateral part.

(H XX) iv. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus pterygoideus dorsalis medialis

(DAVIDS, 1952, pp. 529, 533)

This muscle runs as the other parts of the musculus pterygoideus a) from the arcus palato-pterygoideus, in this case from the lateral surface of the pterygoid, b) towards the medial surface of the lower jaw.

1a. Musculous attachment. This occurs with the dorsal muscle fibres on the lateral surface of the pterygoid, except the posterior part, to which some muscle fibres of the musculus adductor mandibulae posterior are attached.

Attachment by means of an external aponeurosis. The aponeurosis (34) is in my opinion probably an external aponeurosis; it lies at the border of the area of attachment. This aponeurosis (34) adjoins the lateral border of the pterygoid. The ventral muscle fibres are attached to it.

1b. Musculous attachment. This occurs to the largest part of the base of the processus angularis internus; it runs downwards in a rostral direction towards the medial surface of the lower jaw.

Attachment by means of an external aponeurosis. This occurs with the dorsal muscle fibres by means of an aponeurosis, which is in my opinion probably an external aponeurosis, as the crista (35) to which it is attached lies on the dorsal border of the lower jaw.

2a. Surface of the area of attachment. This area on the lateral surface of the pterygoid is concave. It extends dorsalwards up to on the costa (33) which lies between the strong crista (24) and the facet of the basipterygoid articulation.

2b. Surface of the area of attachment. The area on the medial surface of the lower jaw is concave.

The crista (35) is small.

(H XX) v. *Columba palumbus palumbus* L. (Columbae; Aves)

a Musculus depressor mandibulae

(ROOTH, 1953, pp. 261-263; personal communication)

This muscle runs a) from the occiput, b) to the lower jaw. It shows three parts: a superficial medial part, a superficial lateral part and, between these two, a "medial part" which contains the ligamentum depressor mandibulae.

1a. Musculous attachment. This occurs with a part of the muscle fibres of the superficial lateral part of the muscle in their attachment to a part of the surface of the squamosum lying ventro-rostrally of crista (4); this musculous attachment is rather loose. — The attachment of the "medial part" of the muscle takes place on the ventral surface of the broad ligamentum depressor mandibulae which connects the lower jaw with the skull near the cavum tympani.

Attachment by means of an external aponeurosis. This aponeurosis (5) is no doubt an external aponeurosis (personal communication); the muscle fibres are attached to the dorsal surface of aponeurosis (5). To this well developed aponeurosis (5) the superficial medial part of the muscle is attached. This aponeurosis (5) is attached to the crista (5), which is situated caudo-medially of the cavum tympani.

Attachment of the superficial lateral part of the muscle by means of aponeurosis (4), which is no doubt an external aponeurosis (personal communication); the attachment of the muscle fibres takes place on the ventral surface of this aponeurosis. This aponeurosis (4) is attached to the crista (4), which is situated a little caudo-dorsally of the processus temporalis running in a ventro-caudal direction.

1b. Musculous attachment. This occurs with the muscle fibres of the "medial part" of the muscle on the triangular caudal surface of the lower jaw.

Attachment by means of an external aponeurosis. This occurs with the muscle fibres of the superficial medial part of the muscle by means of aponeurosis (12) which is no doubt an external aponeurosis (personal communication); the muscle fibres are attached on the lateral surface of this aponeurosis (12). This aponeurosis (12) is attached to crista (12) which borders the caudal surface of the lower jaw at the medial side.

Attachment in an aponeurotic way of the muscle fibres of the superficial lateral part of the muscle by means of the strongly developed aponeurosis (11), which is no doubt an external aponeurosis (personal communication); the muscle fibres are attached to the medial surface of this aponeurosis (11). This aponeurosis (11) is attached to crista (11).

2a. Surface of the area of attachment. This area on the squamosum seems to be flat or a little convex. Crista (4) and (5) have no doubt the shape of a crista.

2b. Surface of the area of attachment. This area on the caudal surface of the lower jaw seems to be a little convex. Crista (11) and (12) have no doubt the shape of a crista. Crista (11) marks the lateral border of the caudal surface of the lower jaw.

3. Mutual course of the muscle fibres. The course of the fibres of the superficial medial part of the muscle is such that these muscle fibres take a rostro-lateral course to the lower jaw. The muscle fibres of the superficial lateral part run in a rostro-ventral direction. The direction of the muscle fibres of the "medial part" of the muscle is rostro-ventralwards and the situation is such that muscle fibres which have the most rostral origin on the ligamentum insert most dorsally on the area of insertion. Consequently these are the shortest muscle fibres. Accordingly the muscle fibres taking their origin more caudally on the ligamentum, have their attachment more ventrally on the area of insertion and so these are the longest fibres.

(H XX) vi. *Ardea cinerea* (L.) (Gressores; Aves)

a. Musculus adductor mandibulae internus pseudotemporalis profundus

(Bas, 1955, pp. 102-103; personal communication)

This muscle runs a) from the rostral or distal part of the processus orbitalis quadrati, b) to the medial surface of the lower jaw.

1a. Musculous attachment. This occurs to the flat rostral or distal part of the processus orbitalis quadrati.

Attachment by means of an external aponeurosis. This surface aponeurosis (14) is no doubt an external aponeurosis with one wall (personal communication). It is attached to crista (14).

1b. Musculous attachment. This occurs to the ventral half of a long shallow groove-like concavity or fossa, which can be taken as an enlarged and open continuation of the canalis primordialis and which lies on the medial surface of the lower jaw.

Attachment by means of an external aponeurosis. This aponeurosis (11) is no doubt an external aponeurosis with one wall (personal communication). It is a rostral surface aponeurosis, which is very slightly developed and which is attached to crista (11).

2a. Surface of the area of attachment. The entire area of attachment, musculous as well as aponeurotic, is more or less convex. The crista (14) is the sharp rostral and medial edge of the rostral or distal part of the processus orbitalis quadrati.

2b. Surface of the area of attachment. The entire area of musculous attachment is slightly concave; it lies in the ventral half of the fossa; it is deepest in its rostral part and caudalwards becomes gradually shallower.

The crista (11) is only slightly developed.

3. Mutual course of the muscle fibres. The most caudal muscle fibres run almost vertically ventralwards from the processus orbitalis quadrati to the lower jaw. As the area of attachment on the lower jaw extends far more rostralwards than the processus orbitalis quadrati, the rostral muscle fibres run in a caudo-dorsal direction from the lower jaw to the rostral and medio-rostral aponeurosis (14).

The area of musculous attachment of the muscle fibres to the distal part of the processus orbitalis quadrati is directed lateralwards halfway the processus and it faces rostro-ventralwards at the top of the processus orbitalis quadrati, owing to a rotation in a caudo-ventral direction of the distal part of this processus from a vertical into a horizontal plane and owing to the fact that this distal part of the processus is curved dorsalwards.

b. Musculus depressor mandibulae

(Bas, 1955, pp. 109-110; personal communication)

This muscle runs a) from an area between the temporal and occipital regions of the cerebral skull, b) to the part of the lower jaw which projects caudally behind the quadratum-articulare joint.

1a. Musculous attachment. This occurs on an area on the cerebral skull which is rather like a dorso-ventrally stretched narrow triangle with slightly concave sides, the top pointing dorsalwards. The caudal side of the triangle is the crista occipitalis, the rostral side is crista (24), the ventral side is constituted by crista (26).

Attachment by means of an external aponeurosis. This aponeurosis (24) is no doubt an external aponeurosis with one wall (personal communication). It is a rostral surface aponeurosis, which is attached to crista (24).

Attachment in an aponeurotic way by means of the aponeurosis (26), which is no doubt an external aponeurosis with one wall (personal communication); it is a rostro-dorsal surface aponeurosis which lies against ligamentum (5) from which it cannot be separated; aponeurosis (26) is attached to crista (26).

Attachment in an aponeurotic way by means of the aponeurosis (28), which is no doubt an external aponeurosis with one wall (personal communication). It is a caudal surface aponeurosis and is attached to the crista occipitalis.

1b. Musculous attachment. This occurs on an area in the shape of a quarter of a circle in a latero-dorsal facing plane on the dorsal surface of the lower jaw. The two straight sides constitute the lateral and rostral borders, the curved side the medial and caudal borders. Along the lateral and caudo-medial borders runs crista (21) (read 21 instead of 19). In its medial part the rostral border is a crista to which ligamentum (5) is attached; in this rostral border, about in the middle, also lies spina (4) to which ligamentum (4) is attached.

Attachment by means of an external aponeurosis. This aponeurosis (21) (read 21 instead of 19) is no doubt an external aponeurosis with one wall (personal communication). This aponeurosis is the caudal surface aponeurosis (21) (read 21 instead of 19) which is attached to crista (21) (read 21 instead of 19) on the lower jaw.

2a. Surface of the area of attachment. This area for the musculous attachment is slightly concave.

The crista (24) branches off from the crista occipitalis somewhat more ventrally than the crista temporalis; this crista (24) is very slightly developed and may be entirely absent at some places.

The crista (26) is small and sharp; it is horizontal and runs from just caudally of the squamosum-quadratum joint in a medio-caudal direction and connects the ventral ends of crista (24) and of the crista occipitalis.

The crista occipitalis is distinctly developed, as the figures show.

2b. Surface of the area of attachment. According to the figure this area for musculous attachment is slightly concave.

The crista (21) (read 21 instead of 19) on the lower jaw is not very distinctly developed, according to the figure.

3. Mutual course of the muscle fibres. The most rostral part of the muscle runs from the central and rostral part of the place of attachment on the lower jaw in a dorsal direction to the rostro-dorsal aponeurosis (26) as well as to the basal part of the triangular area of attachment on the cerebral skull.

The caudal part of the muscle runs from the narrow strip on the lower jaw along the lateral and caudo-medial borders of the place of attachment as well as from the caudal aponeurosis (21) (read 21 instead of 19) to the cerebral skull; here it is attached musculously on the dorsal part of the triangular area of attachment as well as in a slightly aponeurotic way by means of the aponeurosis (24) and of the aponeurosis attached to the crista occipitalis (dorsalwards the attachment extends by means of aponeurosis (28) along the crista occipitalis as far as close to the dorsal median).

There is no difference in the direction of the muscle fibres in the rostral and the caudal parts of the muscle.

(H XX) vii. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus depressor mandibulae

(Bams, 1956, pp. 85-89; personal communication)

This muscle runs a) from the caudo-latero-ventral side of the neurocranium in a dorso-ventral direction, b) to the medio-dorsal surface of the caudal part of the lower jaw. When the bill is closed this muscle is about three times as long as broad.

1a. Musculous attachment. This occurs to the regio deltoides, a triangular space, bordered rostro-dorsally by the crista (c.a.), caudo-dorsally by the crista (c.b.), and ventrally by the edge (c.d.). This musculous attachment occurs to the raised edge of the cristae (c.a.) and (c.c.) and also on the most dorsal part of the regio deltoides with all the muscle fibres ending in aponeurosis (I). There is also a musculous attachment to the regio deltoides of a part of the muscle fibres which are musculously attached to the lower jaw; this attachment is found at an angle of 60-80° when the bill is closed.

Attachment by means of an external aponeurosis. The aponeurosis (II) is no doubt an external aponeurosis with one wall (personal communication). It is a surface aponeurosis, lying on the medial side of the muscle belly. It is the more median part of the muscle fibres which is attached to aponeurosis (II); these muscle fibres run to the lower jaw. This rather strongly developed aponeurosis (II) is attached to the edge (c.d.) and gradually decreases in thickness and ends a little rostrally of the medial border of the region of the lower jaw bearing the jaw joint. This aponeurosis (II) does not extend caudally to the "tendon PQ", a very strong cylindrical "tendon" which connects the point (P) on the ventral edge (c.d.) of the regio deltoides with the point (Q) on the skeletal lower jaw.

1b. Musculous attachment. This occurs to the caudo-dorsally directed part of the surface of the lower jaw situated caudally of the cavitas glenoidalis.

Attachment by means of an external aponeurosis. The aponeurosis (I) is no doubt an external aponeurosis with one wall (personal communication). This surface aponeurosis lies on the lateral surface of the muscle. This aponeurosis (I) is more strongly developed; it is attached to the lower jaw and runs as far as about half way its length. Aponeurosis (I) does not cover the surface smoothly: its shape is complicated because half way the line of its attachment it is folded inwards as deep as about 1 mm. This fold gradually becomes shallower and shallower until the aponeurosis lies entirely in the plane of the surface. Because of this fold the breadth ventrally at the ventral place of attachment has decreased considerably, *i.e.* from 10 to 8 mm, so 2 mm.

2a. Surface of the area of attachment. The regio deltoides is not entirely occupied by the attachment of muscle fibres. This is due to the fact that this surface makes a very acute angle with the direction of the muscle fibres and as it is somewhat undulating, two strips occur where the angle is practically zero, so that attachment is impossible.

The crista (c.a.) and (c.b.) is considered a crista. The crista (c.d.) is considered an edge.

2b. Surface of the area of attachment. No details are given in the description.

3. Mutual course of the muscle fibres. When the bill is closed, the muscle, seen from the lateral side, shows a slightly S-shaped curve.

The direction of the muscle fibres — apart from a slight curve — is straight and in the whole belly of the muscle for all muscle fibres is practically parallel, at least the muscle fibres never cross each other.

All the muscle fibres ending in aponeurosis (I) are attached musculously to the neurocranium.

The superficial muscle fibres run somewhat divergingly towards the broadest part of the muscle belly. This effect is still enhanced by the narrowing of the aponeurosis (I), which is a common phenomenon in a certain type of muscles to which this one undoubtedly belongs.

The rostral ones of the most superficial fibres of this muscle belong to the external and longest fibres, which are attached to aponeurosis (I); they are all attached to cristae (c.a.) and (c.c.). As they lie more laterally than the height of the cristae, they curve medialwards at the level of the cristae. The same occurs with fibres of the musculus adductor superficialis, which are also attached to these cristae; the fibres of both these muscles together form a weak aponeurosis.

Caudally a part of the muscle fibres are attached to crista (c.b.), while the remaining fibres are attached by means of the aponeurosis of the musculus rectus capitis lateralis; this aponeurosis is attached to the crista occipitalis (c.o.) (the muscle fibres of the musculus depressor mandibulae end in a thin layer of connective tissue lying on this aponeurosis). — As the angle between the pulling directions of the musculus depressor mandibulae and of the musculus rectus capitis lateralis amounts to about 90°, the contraction of the muscle fibres of the musculus depressor can yield a maximal effect only when the musculus rectus capitis lateralis contracts simultaneously and thereby fixes the point of action in relation to the skull. It is not self-evident that this will always be the case. It is a fact, however, that only that part of the aponeurosis is concerned, which is least movable, *i.e.* the part closest to the line of attachment.

Heading XXI: internal aponeurosis + external aponeurosis — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XXII: musculous + internal aponeurosis — musculous + external aponeurosis

(H XXII) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus hyohyoideus ventralis

(SARKAR, 1960, pp. 55-58; 113)

This muscle runs a) from the entire ventral and lateral surfaces of the broad expanded wing-like expansion in the region of the branchiostegal rays and from the antero-ventral tubers of the 1st, 2nd and 3rd branchiostegal rays, b) to the hypohyale and to the anterior part of the ceratohyale. This muscle is a long cylindrical muscle equal to about two-thirds of the length of the head. Seen from the ventral side the muscle appears to be roughly divided into two parts: the ventral part and the ventro-lateral part.

1a. Musculous attachment. This occurs to the entire ventral and lateral surfaces of the broad expanded wing-like expansion in the region of the branchiostegal rays. This area of attachment is very broad. The wing-like expansion has a narrow anterior end near its articulation with the ceratohyale and a broad posterior part. To the dorsal surface of this wing-like expansion also a portion of the dorsal part of the muscle is attached. The bundle of muscle fibres which is present towards the middle of the head and which is musculously attached to the ventral border of the ceratohyale on the one end, is attached musculously to the remaining anterior portion of the lateral ridge of the wing-like expansion on the other end; the other portion of this lateral ridge is occupied by a portion, of the ventral part of the muscle.

Attachment by means of an internal aponeurosis. This aponeurosis (23) is in my opinion perhaps an internal one. It is attached to the antero-ventral surface of the prominent antero-lateral triangular crista (7) on the articulating anterior region of the wing-like structure. The area of attachment on this crista (7) is linear. The pointed part of the crista (7) is directed ventrally.

Another attachment by means of internal aponeuroses occurs with aponeuroses which are in my opinion perhaps internal ones. These aponeuroses are attached to the antero-ventral surfaces of the first three branchiostegal rays. The areas of attachment on the branchiostegal rays are very narrow and somewhat rounded; it covers the region between the area of attachment of the musculus geniohyoideus and a point halfway along the branchiostegal rays. The 1st branchiostegal ray has a short rounded process, previously referred to as a tuber. The 2nd branchiostegal ray bears a similar short process but the rest of the rays have none. To the tuber of the 1st branchiostegal ray and to similar areas of the 2nd and 3rd branchiostegal rays aponeuroses are attached to which a small posterior portion of the bifurcation of the bundles of the ventro-lateral part of the muscle, lying along the two sides of the caudo-ventral crista of the ceratohyale, is attached.

1b. Musculous attachment. This occurs with the ventral part of the muscle to the ventro-medial surface of the very small hypohyale and the adjacent area of the antero-medial surface of the ceratohyale.

Another musculous attachment occurs with the very large dorsal part of the muscle to the dorsal surfaces of the hypo- and ceratohyalia, where they unite; anteriorly the dorsal parts of the muscles of the right and left sides are fused to appear like a single muscle. This dorsal part is also attached to half of the dorso-lateral border of the ceratohyale. The muscle fibres attached to this area are directed dorso-medially, where they are fused with similar fibres coming from the opposite side, just over the slender urohyale.

A third musculous attachment occurs with some bundles of the ventro-lateral part of the muscle to the antero-ventral border as well as to much of the lateral surface of the ceratohyale. The bundle of muscle fibres which is present towards the middle of the head is musculously attached at an angle of 45°-50° to the ventral border of the ceratohyale, slightly posterior to the anterior union of the hypo- and ceratohyalia; this bundle runs straight caudally. The bundles next to this are attached musculously to the antero-lateral surface of the ceratohyale in common with the dorsal part of the muscle. More bundles, posterior to these, are also musculously attached to the grooved antero-medial surface of the ceratohyale.

Attachment by means of an external aponeurosis. The aponeurosis (also numbered (23)) is in my opinion perhaps an external aponeurosis, judging from its position in relation to that of the areas of musculous attachment. This aponeurosis (23) is attached to a small area on the medial surface of the ceratohyale.

Another attachment in an aponeurotic way occurs by means of an aponeurosis, bearing no number in the text, and which is in my opinion perhaps also an external aponeurosis. This aponeurosis is formed by the straight, most lateral bundle, running antero-posteriorly, along with the centrally directed muscle fibres from the postero-lateral side. This aponeurosis is attached to the ventral border of the anterior part of the ceratohyale. Near its anterior attachment this aponeurosis meets muscle fibres of other regions of this ventral part of the muscle. It is perhaps attached to crista (5) of the ceratohyale; this crista (5) shows an aponeurotic attachment.

2a. Surface of the area of attachment. The wing-like expansion in the region of the branchiostegal rays is broad and expanded; it bears the very broad area of attachment on its ventral and lateral and also on its dorsal surface.

The antero-lateral triangular crista (7) is prominent; the area of attachment is linear.

The short rounded process on the 1st branchiostegal ray has previously been referred to as a tuber; the 2nd branchiostegal ray bears a similar short process; the rest of the rays have none.

2b. Surface of the area of attachment. The area of attachment on the hypohyale is narrow, elongated and directed antero-posteriorly. On the ceratohyale the area of attachment is broader and lies in a groove.

The area of attachment to the dorsal surfaces of the hypo- and the ceratohyalia is not described in detail.

The area of attachment to the antero-ventral border and to the lateral surface of the ceratohyale is not described in detail; the antero-medial surface of the ceratohyale is considered to be grooved.

The area of attachment of the aponeurosis on the medial surface of the ceratohyale is a grooved surface between the thin ventral edge (6) and the prominent costa (5) along the dorsal side and thus restricted to the anterior half of the bone.

The area of attachment of the presumably external aponeurosis on the anterior part of the ceratohyale occurs on its ventral border. Crista (5) on the ceratohyale has the shape of a crista.

3. Mutual course of the muscle fibres. This may be derived from the following indications.

The muscle is a long cylindrical one, seen from the ventral side roughly divided into a ventral and a ventro-lateral part.

The ventral part of the muscle is narrow anteriorly and broad posteriorly. The posterior broadening of the muscle takes the shape of the wing-like expansion to which it is attached. The ventral superficial muscle fibres run posteriorly in a straight line. All the centrally directed muscle fibres converge to meet the straight, most lateral bundle running antero-posteriorly.

The dorsal part of the muscle is a very thick portion of the muscle.

As to the ventro-lateral part of the muscle the bundle of muscle fibres which is present towards the middle of the head runs straight caudally and then curves laterally. The remaining bundles of this ventro-lateral part of the muscle curve ventrally. This part of the muscle shows a bifurcation on the posterior side.

(H XXII) ii. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus pseudotemporalis superficialis

(Davids, 1952, pp. 86-90)

This muscle runs a) from the medial surface of the lower jaw to an area on the dorso-rostral side of the foramen pro ramo mandibulare nervi trigemini, b) to the caudal wall of the orbita in a rostro-ventral and a little lateral direction.

1a. Musculous attachment. This occurs to an oblong area, which lies on the rostro-dorsal side of foramen V3.

Attachment by means of an internal aponeurosis. The attachment of a part of the muscle fibres to the aponeuroses (7) and (9) takes place on the medial surface of these aponeuroses; to the lateral surface of these aponeuroses, however, the muscle fibres of the musculus adductor mandibulae externus are attached; both these aponeuroses (7) and (9) cover the medial side of the latter muscle. Thus the muscle fibres of both muscles are implanted on the opposite surfaces and the aponeuroses (7) and (9) are internal aponeuroses.

1b. Musculous attachment. This occurs to an area which shows a pointed inner or medial and a pointed ventral end, the medial one ending with tuber (10), the ventral one extending along the rostral border of the foramen pro ramis maxillare et mandibulare nervi trigemini.

Attachment by means of an external aponeurosis. The aponeurosis (10) is in my opinion probably an external aponeurosis.

2a. Surface of the area of attachment. This area is convex. The aponeuroses (7) and (9) lie on the rostral *resp.* caudal side of a bony tuberosity on the dorsal border of the lower jaw.

2b. Surface of the area of attachment. This area has the shape of a convex vault, corresponding with the area of the lobus opticus. The aponeurosis (10) is attached on a tuber.

3. Mutual course of the muscle fibres. Those fibres, showing a musculous attachment to the wall of the orbita, are attached at nearly right angles to this bone. The muscle fibres showing a musculous attachment to the lower jaw are attached at rather sharp angles.

b. Musculus protractor quadrati

(DAVIDS, 1952, pp. 526, 528-529)

The musculus protractor quadrati runs a) from an extended area of the caudal wall of the orbita, b) towards a smaller area, which for the larger part lies on the medial surface of the quadratum.

1a. Musculous attachment. This occurs on the caudal wall of the orbita, reaching ventralwards the rostrum sphenoidale and approaching the anterior border of the basitemporal plane.

Attachment by means of an internal aponeurosis. This aponeurosis (25) is in my opinion probably an internal aponeurosis, as the area of musculous attachment surrounds this crista (25) all around. A few muscle fibres show an attachment to this small aponeurosis (25), which is attached to a crista (25).

1b. Musculous attachment. This occurs on the processus orbitalis quadrati and on the corpus quadrati.

Attachment by means of an external aponeurosis. The attachment of a group of lateral fibres occurs by means of an aponeurosis (13), which is in my opinion perhaps an external aponeurosis; it lies at the height of crista (13) on the lateral surface of the processus orbitalis.

The attachment by means of another aponeurosis occurs with aponeurosis (26), attached to crista (26); as this crista lies at the border of the area of musculous attachment on the corpus quadrati, this aponeurosis (26) is in my opinion probably an external aponeurosis. This aponeurosis (26) is attached to crista (26).

2a. Surface of the area of attachment. This area is convex in its ventral part, owing to the dilatation of the rostrum sphenoidale and its caudalward continuation in two convex vaults. Dorsalwards this area of musculous attachment is partly flat, partly concave.

2b. Surface of the area of attachment. The area of musculous attachment on the medial surface of the processus orbitalis quadrati is concave and on the corpus quadrati it is convex.

3. Mutual course of the muscle fibres. The dorsal muscle fibres run nearly ventralwards in the direction of the quadratum, the ventral muscle fibres run in a caudal-markedly lateral direction.

c. Musculus pterygoideus dorsalis lateralis

(DAVIDS, 1952, pp. 529, 531-533)

This muscle runs as the other parts of the musculus pterygoideus a) from the arcus palato-pterygoideus, in this case from the posterior part of the palatinum, b) towards the medial surface of the lower jaw.

1a. Musculous attachment. This occurs with the most dorsal muscle fibres to the palatinum.

Attachment by means of an internal aponeurosis. The ventral muscle fibres are attached by means of an aponeurosis (30), which is in my opinion probably an internal aponeurosis, judging from one of the figures, though this aponeurosis is attached to the ventral border of the vertical plate, formed by the posterior part of the palatinum.

1b. Musculous attachment. This occurs to a long stretch above the ventral border of the lower jaw; caudalwards this muscle climbs on the convex vault of the basal part of the processus angularis internus.

Attachment by means of an external aponeurosis. The two weak aponeuroses (31), (32), are in my opinion probably external aponeuroses, as the cristae (31), (32) lie on the dorsal limit of the area of attachment; one of the two lies on the processus angularis internus.

2a. Surface of the area of attachment. This area on the posterior part of the vertical plate which extends from the ventral border of this plate as far as the processus palatinus of the pterygoid above, is slightly concave.

2b. Surface of the area of attachment. This area in front of the processus angularis internus is concave.

3. Mutual course of the muscle fibres. The muscle fibres radiate from the palatinum towards the medial side of the lower jaw. The most dorsal muscle fibres mentioned above, run downwards in a latero-ventral direction. The ventral muscle fibres radiate very much. The rostral muscle fibres are attached at a rather sharp angle, the caudal muscle fibres, however, at a very sharp angle.

Heading XXIII: musculous + internal aponeurosis — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XXIV: musculous + external aponeurosis — internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XXV: musculous + internal aponeurosis — musculous + internal aponeurosis + external aponeurosis

(H XXV) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus adductor maxillae part $A_1m\alpha$

(SARKAR, 1960, pp. 38-40, 99, 102-103, 113)

This muscle runs a) from the cerebral skull, b) to the dorsal half of the maxilla. This muscle is approximately square. It can be divided into three parts.

1a. Musculous attachment. This occurs with the first part of the muscle to the latero-caudal surface of the palatinum, to the entire dorsal surface and to the ventro-lateral surface of the praefrontale. The somewhat elongated and narrow area of attachment to the palatinum lies on the caudally directed process. The area of attachment on the dorsal surface of the praefrontale is triangular and shows a considerable width; the area of attachment on the dorsal surface is bordered by the free edges of the praefrontale and the ridge, separating the frontale and the praefrontale. The area of attachment to the ventro-lateral surface of the praefrontale is small and narrow; it is restricted to the laterally extended anterior arm of the praefrontale.

A second area of musculous attachment occurs with the second part of the muscle, partly to the entire lateral surface of the parasphenoid and partly to the medial half of the lateral process of the parasphenoid. The area of attachment to the lateral surface of the parasphenoid is an elongated triangular one. The area of attachment to the medial half of the lateral process of the parasphenoid is a short rough one.

A third area of musculous attachment occurs with the greater portion of the third part of the muscle to the entire ventral surface of the praefrontale and the ventral surface of the latero-ethmoid. On the ventral surface of the praefrontale the area of attachment is as broad as that of the first part of $A_1m\alpha$ which is attached to its dorsal surface. The praefrontale is a wing-like structure, the anterior edge of which is flat, thin and extended laterally. The remaining posterior part of the muscle is musculously attached to a comparatively shorter area on the ventral surface of the latero-ethmoid. This area of attachment is rectangular, lying just dorsal to the connection with the palatinum; no border-lines can be distinguished.

The shape of the praefrontale may be regarded as a structure adapted to the tension of the muscular forces acting on it. The slight rostral sloping of the praefrontale is in the direction of the working-line of the two parts of musculus $A_1m\alpha$. Forces acting on them (horizontal and vertical components) act on the praefrontale at different angles. These forces cause bending stresses and tension stresses on the praefrontale. To resist these stresses the praefrontale has to possess a certain shape. If the praefrontale is considered a beam fixed on one side to the frontale, the expected shape is a plate, more or less triangular in cross section and also in sagittal section.

Attachment by means of an internal aponeurosis. This occurs with the aponeurosis (9) which is an internal aponeurosis. Muscle fibres are attached to both surfaces of this aponeurosis but at different angles; the most ventral fibres which run to the area, ventral to the pointed lateral part of the praefrontale, curve a little ventrally from the rostral aponeurosis. Midway, they meet some tangentially directed fibres running to the aponeurosis (9). This thin short aponeurosis faces laterally; it is connected to the pointed lateral end of the anterior surface of the praefrontale.

1b. Musculous attachment. This occurs with a small anterior portion of the third part of the muscle part to the dorsal half of the maxilla, close to the attachment by the common aponeurosis (8). Both the musculous and the aponeurotic attachments make an angle of approximately 90° with the maxilla.

Attachment by means of an internal aponeurosis. This is the case with the aponeurosis (8), which is an internal aponeurosis, the muscle fibres starting from both surfaces. This aponeurosis (8) is a common aponeurosis which attaches rostrally all three parts of the muscle to the dorsal half of the maxilla. The area of attachment for aponeurosis (8) is narrow and lies on the rounded elevated ridge of the caudo-medial surface of the maxilla. The aponeurosis (8) runs caudally and somewhat dorsally.

Attachment by means of aponeuroses either internal or external. In a number of cases the character of the aponeurosis is not mentioned. As very probably also external aponeuroses are present among them, we brought this muscle under this heading XXV. We have in mind the aponeuroses (10), (11), (12) and (13).

Anteriorly the aponeurosis (10) does not bear any muscle fibres. The middle of the aponeurosis (10) is thickened in the form of an elevated tendinous structure. This aponeurosis (10) runs caudally, ventral and medial to the common aponeurosis (8). Near its place of attachment this aponeurosis (8) splits off the aponeurosis (10) from its ventral surface.

The aponeurosis (11) is split off from the dorsal surface of the aponeurosis (10). This aponeurosis (11) runs between the aponeuroses (8) and (10).

The small aponeurosis (12) starts from the periosteum of the pterygoid plate and joins the aponeurosis (10) on its ventral surface.

The aponeurosis (13) is connected to the middle area of the rostral edge of the praefrontale. The area of this thin aponeurotic attachment is narrow.

2a. Surface of the area of attachment. No detailed description is given.

2b. Surface of the area of attachment. This area on the dorsal part of the maxilla is much broader than that of the common aponeurosis (8) and lies in the deep groove of the maxilla. It occupies the ventral half of the groove and has the shape of a rectangle, of which two sides are formed by the caudally directed elevation and the rounded ridge. The other two sides have no prominent lines of demarcation.

3. Mutual course of the muscle fibres. The muscle fibres of the first part of the muscle which start from the anterior part of the aponeurosis (8) are directed to the processus nasalis of the palatinum in a caudo-dorsal direction. The angle of attachment of these muscle fibres with the aponeurosis varies from 30°-20° (rostral to caudal). The muscle fibres which start from the posterior part of the aponeurosis are directed to the dorsal surface of the praefrontale almost in line with it, whereas the muscle fibres to the lateral side of the praefrontale make a more acute angle.

The muscle fibres of the antero-dorsal part of the second part of the muscle run from the aponeurosis (10) of the mid-tendon caudo-medially. The muscle fibres of the caudo-dorsal part of the muscle, which have their attachment on the caudal part of the parasphenoid, are directed more caudally from the aponeurosis, whereas the muscle fibres to the lateral process of the parasphenoid run more caudo-ventrally. The lengths of all the muscle fibres mentioned are almost the same, laterally as well as medially.

The greater portion of the third part of the muscle runs from the aponeurosis (11) to the ventral surfaces of the praefrontale and of the latero-ethmoid.

The musculus $A_1m\alpha$ shows an alternation of aponeuroses.

b. Musculus dilatator operculi pars lateralis

(Sarkar, 1960, pp. 45-49, 113)

This muscle runs a) from the anterior half of the suboperculum, from the ventral part of the operculum, from the costa (4) and the spina of the operculum, b) towards the lateral end of the squamosal process. The muscle is long and has the shape of an elongated triangle. It extends from caudo-ventral to dorsal.

1a. Musculous attachment. This occurs to the ventral border of the lateral surface of the operculum as a rectangular area, without special demarcation lines, to the rostral surface of the costa (4) on the operculum, to the ventral border of the triangular crista (2) and to the medial rim of the spina of the operculum which covers a narrow area restricted to the curved part of the spina.

A second area of musculous attachment lies on the lateral surface of the most dorsal of the rostral processes on the suboperculum. This area of attachment is triangular.

Attachment by means of an internal aponeurosis. This is the case with aponeurosis (18), which is in my opinion perhaps an internal aponeurosis. This aponeurosis (18) is caudo-ventrally attached to the dorsal part of the anterior half of the suboperculum. The ventral end of the lateral surface of the rostral part of the muscle tapers and terminates in the aponeurosis (18).

1b. Musculous attachment. This occurs to the caudal surface of the squamosal process with a part of the short fibres which are dorsally attached.

Attachment by means of an internal aponeurosis. This is the case with the tendo (2) which is in my opinion probably an internal tendo. This tendo (2) is attached to the extreme lateral part of the laterally projecting caudal squamosal process; this lateral end, which is semi-circular and narrow, also serves for the attachment of the dorsal aponeurosis (17). The tendo (2) is attached ventrally to the aponeurosis (17). Both the tendon (2) and the aponeurosis (17) make an angle of attachment of about 80° with the squamosal process. To this big strong tendo (2) are attached: the medial muscle fibres of both the rostral and the caudal parts of the muscle, which ventrally shows a bifurcation over the ventral one-third of the costa (4) of the operculum, so that the muscle can be divided into these two parts. The tendon (2) belongs mainly to the caudal part of this muscle. Some short muscle fibres which are dorsally attached, are partly attached to the dorsal tendon (2).

A second case is aponeurosis (17), which is in my opinion perhaps also an internal aponeurosis, judging from the figures. The dorsal end of the lateral surface of the rostral part of the muscle tapers and terminates in the aponeurosis (17). Dorsally some medial muscle fibres of the rostral part are connected to the medial surface of the aponeurosis (17) of the lateral bundles. Similarly, some medial muscle fibres of the caudal part come from the dorsal aponeurosis (17).

Attachment by means of an external aponeurosis. In my opinion the aponeurosis (17a) is no doubt an external aponeurosis with one wall. It is a thin superficial aponeurosis; its length is about half of the whole length of the muscle. Into this aponeurosis (17a) a few bundles of muscle fibres from their ventral attachment to the anterior process of the suboperculum converge.

2a. Surface of the area of attachment. This area on the lateral surface of the most dorsal of the rostral processes on the suboperculum is a flat area without any structure of demarcation.

The dorso-rostral surface of the crista (3) of the operculum to which muscle fibres are musculously attached is concave.

2b. Surface of the area of attachment. No detailed description is given.

3. Mutual course of the muscle fibres. The muscle shows, ventrally, a bifurcation over the ventral one-third of the costa (4) of the operculum, so that the muscle can be divided into a rostral and a caudal part. — The muscle fibres of the lateral surface of the rostral part of the muscle, terminating in aponeuroses (17) and (18), taper to the dorsal and ventral ends, while the middle portion is broad and forms the venter. A narrow muscle bundle of this rostral part is attached to the costa (4) and some fibres are attached to the connective tissue plate just rostrally to the costa (4). There are a number of muscle bundles, running in different directions, *e.g.* caudo-laterally and caudo-dorsally. — The muscle fibres of the caudal part are attached at an angle of 45° to the operculum. Some muscle fibres cross the costa (4) and run from the rostral part to the caudal part in a dorsal-ventral direction. — This muscle part shows an alternation of aponeuroses.

(H XXV) ii. *Phalacrocorax carbo sinensis* (Shaw & Nodder) (Steganopodes; Aves)

a. Musculus adductor mandibulae externus profundus and musculus adductor mandibulae posterior

(Dullemeijer, 1951, pp. 253-254)

It is almost impossible to separate these two muscles from each other and from the musculus adductor mandibulae externus superficialis. These two muscles run a) from a part of the lower jaw, rostral and rostro-medial of the rostral joint-cavity, b) to the latero-rostral surface of the quadratum.

1a. Musculous attachment. This occurs to the triangular area on the surface of the knob of the joint of the lower jaw and to the dorsal quarter of the upper side of the vertical plate which is the shape of the lower jaw in this region, rostrally of the joint.

Attachment by means of an internal aponeurosis. This takes place to a crista, which lies in front of the rostral joint-cavity and is directed transversely on the lower jaw.

1b. Musculous attachment. This occurs to an area on the latero-rostral surface of the quadratum.

Attachment by means of an internal aponeurosis. This occurs to the crista which forms the rostro-ventral limit of the latero-dorsal knob of the quadratum; this internal aponeurosis is the most lateral of the three aponeuroses.

Attachment by means of an external aponeurosis. In my opinion the surface aponeurosis to be mentioned is an external aponeurosis with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeurosis. The attachment of the muscle to the ventral sharp ridge of the processus orbitalis takes place by means of a surface aponeurosis lying on the medial surface of the muscle and constituting the most medial one of the three aponeuroses.

2a. Surface of the area of attachment. The triangular area on the surface of the knob of the joint is probably a little concave. The area of attachment on the dorsal quarter of the upper side of the plate-like lower jaw cannot be separated from that of the musculus adductor mandibulae externus superficialis. This area extends from the oval crista to a transverse crista; it is a convex surface lying at the bottom of a depression. The crista to which the internal aponeurosis is attached is a little crista.

2b. Surface of the area of attachment. This area is a shallow fossa of the quadratum. The crista of the most lateral (internal) aponeurosis is apparently low. The processus orbitalis is a flattened long-drawn triangular processus which is directed rostralwards.

3. Mutual course of the muscle fibres. The internal aponeurosis on the little crista on the lower jaw alternates with both the aponeuroses on the quadratum, with the most lateral internal aponeurosis and with the most medial external (surface) aponeurosis. Thus there is a system of side-scenes. Part of the muscle fibres run from one aponeurosis to the other, forming interrupted zigzag lines. At the medial side only the muscle is covered by an external aponeurosis; at the lateral side only muscle fibres run to the lower jaw where they are attached musculously. As to the middle portion of the muscle, limited by the planes of the two terminal aponeuroses and their produced parts, we also find within this space muscle fibres running to the quadratum and to the lower jaw.

b. Musculus adductor mandibulae internus pterygoideus

(DULLEMEIJER, 1951, pp. 255-259; personal communication)

This muscle runs a) from the dorsal and the ventral surface of the palatinum and from the ventral surface of the pterygoid, b) to the medial surface of the lower jaw, behind and below the jaw joint and below the canalis primordialis.

1a. Musculous attachment. This occurs to the entire dorsal surface of the palatinum, to the caudal part of the ventral surface of the palatinum, to the ventral surface of the crista-like lateral wing of the pterygoid and to the ventral surface of the crista-like medial wing of the pterygoid.

A t t a c h m e n t b y m e a n s o f a n i n t e r n a l a p o n e u r o s i s. This aponeurosis (H) is an internal aponeurosis, part of which shows the characters of an external aponeurosis. As far as this aponeurosis (H) is attached to the lateral wing of the pterygoid it is an internal aponeurosis, the muscle fibres arising from both surfaces of this aponeurosis. This part of the aponeurosis decreases in size and thickness on the lateral wing of the pterygoid and ends halfway of the pterygoid. The attachment to the crista-like short dorso-medial diverging wing of the pterygoid and to the long dorso-lateral diverging wing of the pterygoid occurs by means of aponeuroses, of which we described that on the lateral wing. The attachment to the elliptic crista running all round along the border of the area of musculous attachment on the caudal part of the ventral surface of the palatinum also occurs by means of this aponeurosis (H). As far as this aponeurosis (H) is attached to the palatinum it lies on the surface of the muscle; thus this part of the aponeurosis (H) shows the characters of an external aponeurosis, with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeurosis. The medial side of this part of the aponeurosis is the strongest one; it increases caudad in thickness and becomes tendon-like on the most caudal point of the palatinum.

1b. M u s c u l o u s a t t a c h m e n t. This occurs to the medial surface of the lower jaw from a point below the centre of the oval fossa of the canalis primordialis to the most caudal point of the lower jaw.

A t t a c h m e n t b y m e a n s o f a n i n t e r n a l a p o n e u r o s i s. This is found as the strong aponeurosis, attached to the caudal crista at the end of the lower jaw. The attachment of a separate muscle bundle to the little crista or spina which constitutes the most lateral part of the transverse crista occurs by means of an internal tendon.

A t t a c h m e n t b y m e a n s o f a n e x t e r n a l a p o n e u r o s i s. The aponeurosis (J) must be considered as an external aponeurosis with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeurosis. The aponeurosis (J) arises in a tendinous way, running rostralwards it becomes more flattened and then passes into an aponeurosis at the dorsal surface of the muscle. The aponeurosis (J) is attached to the truncated spina. To the most caudal point of this caudal crista a small aponeurosis (I) is attached; this is a surface aponeurosis (an external aponeurosis with total loss of one of the walls).

2a. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. The area of musculous attachment on the dorsal surface of the palatinum is flat and shows no differences between the rostral and caudal part. The area of musculous attachment on the ventral surface of the whole caudal part of the palatinum shows a depression. There is another little depression on this surface on the lateral side of the elliptic crista which runs all round along the border of the area of musculous attachment, before the point where this crista reaches the lateral edge of the palatinum; this little depression forms a very slight dorsal bending of the edge. The surfaces of these depressions are rough.

The paramedial crista on the ventral surface of the palatinum is a rising crista, increasing in height caudad. Near the change of the caudal into the rostral part the crista becomes much lower. In its caudal part this lateral crista continues as a crista-like lateral edge of the palatinum. This paramedial crista of the palatinum continues a short way on the pterygoid. The short dorso-medial diverging wing of the pterygoid and the long dorso-lateral diverging wing of the pterygoid may be called cristae.

2b. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. This area of musculous attachment on the lower jaw shows a little depression below the jaw joint; this depression gradually changes rostrally into the surrounding bone-surface.

The truncated spina is a strong elevation with a rough surface; it lies close behind the oval fossa of the canalis primordialis and dorsally of the depression.

The crista at the end of the lower jaw is long-drawn and vertical; it lies close behind the joint-cavity and dorsal to the depression. The most caudal point of this vertical crista is spina-like. The transverse crista of which the little crista constitutes the most lateral part, lies close before the jaw joint.

3. Mutual course of the muscle fibres. As to the course of the muscle fibres we can distinguish that of a number of groups of muscle fibres. The majority of the muscle fibres of the strong bundle of the musculus adductor mandibulae internus pterygoideus which are attached to the area of musculous attachment on the medial surface of the lower jaw will run to the area of musculous attachment on the ventral surface of the palatinum and of that on the ventral surface of the pterygoid.

Part of the muscle fibres musculously attached to the ventral surface of the palatinum are attached to the aponeurosis attached to the caudal crista.

The greater part of the muscle fibres which come from the ventral surface of the pterygoid run to the strong aponeurosis attached to the caudal crista.

A separate bundle of the musculus adductor mandibulae internus pterygoideus is attached musculously to the lateral groove of the pterygoid; this bundle can hardly be divided into two conical parts; these rostral and caudal parts lying with their longitudinal axes parallel, meet on a very little tendon which is attached to the little spina, constituting the most lateral part of the transverse crista on the lower jaw.

Muscle fibres musculously attached to the dorsal surface of the palatinum arise from the external aponeurosis (J); a small lateral part of the muscle fibres are attached to the ventro-lateral part of the aponeurosis (H) which bends a little dorsad.

The muscle fibres arising from the medial surface of the internal aponeurosis, attached to the ventral surface of the lateral wing of the pterygoid, run partially to a small aponeurosis (I) which is attached to the most caudal point of the caudal crista of the lower jaw and partially in a musculous way to a little area on a smooth part of the surface of the caudal crista, the sharp top of which is bent rostralwards.

Muscle fibres arising from the ventro-medial and ventro-lateral part of the aponeurosis (H) of the palatinum, run to the strong aponeurosis, attached upon the caudal crista.

The lateral muscle fibres attached on the ventro-lateral internal aponeurosis reach the aponeurosis (J) on the lower jaw.

A small muscle bundle is attached to the medial surface of the medial aponeurosis, halfway this medial aponeurosis; this muscle bundle runs along the connective tissue of the tuba auditiva to the most rostral point of the basisphenoid.

(H XXV) iii. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus pterygoideus ventralis medialis

(Davids, 1952, pp. 529, 531)

This muscle runs as the other parts of the musculus pterygoideus a) from the surface of the lower jaw, in this case the processus angularis internus, b) towards the arcus palato-pterygoideus, in this case the pterygoid and the palatinum.

1a. Musculous attachment. This occurs on the anterior border of the ventral surface and on the entire dorsal surface of the processus angularis internus. This takes place with all the lateral muscle fibres.

Attachment by means of an internal aponeurosis. The aponeurosis (29) is in my opinion probably an internal aponeurosis, as converging it attaches on the medial end of the processus angularis internus. The medial muscle fibres of this muscle (the musculus pterygoideus ventralis medialis) are attached to this aponeurosis (29);

to this aponeurosis all the muscle fibres are attached which are found on the medial side of the musculus pterygoideus ventralis lateralis.

1b. Musculous attachment. This occurs on the ventral surface of the pterygoid and on the caudal end of the palatinum.

Attachment by means of an internal aponeurosis. This aponeurosis (28) is in my opinion perhaps an internal aponeurosis. By means of this narrow aponeurosis (28) a group of lateral muscle fibres are attached. This internal aponeurosis runs from the border of the caudo-ventral wing of the palatinum.

Attachment by means of an external aponeurosis. This aponeurosis (27) is in my opinion probably an external aponeurosis, as it covers the muscle beneath. It is attached to a thin crista on the palatinum.

2a. Surface of the area of attachment. No detailed description is given.

2b. Surface of the area of attachment. The area on the pterygoid shows a slightly concave surface.

3. Mutual course of the muscle fibres. Those showing a musculous attachment on the pterygoid make a very sharp angle with this surface.

The aponeurosis (27) is attached, also at a very sharp angle, on the skeletal surface with the intermediary of the crista (27).

(H XXV) iv. *Ardea cinerea* (L.) (Gressores; Aves)

a. Musculus adductor mandibulae externus

(Bas, 1954, pp. 680-685; personal communication)

This muscle runs a) from the dorsal edge of the lower jaw (caudally of the centre of the eye and rostrally of the quadratum-articulare joint), b) to the temporal region of the cerebral skull and to the lateral surface of the quadratum. This large coherent muscle complex is only incompletely divided by aponeuroses.

1a. Musculous attachment. This occurs on the bony surface of the lower jaw between the crista (1 + 3) and crista (5) and between crista (5) and spina (7).

Attachment by means of an internal aponeurosis. This occurs by means of the internal aponeurosis (1). This aponeurosis (1), which is attached to crista (1), begins as a narrow flat tendon, but soon spreads into a fan-like aponeurosis. There is a rostral part of this fan-shaped internal aponeurosis (1) and a caudal part. The narrow caudal border of this aponeurosis (1) is slightly curved medialwards; this caudal border becomes a plate-shaped aponeurosis in the fossa temporalis rostralis, where this plate-shaped aponeurosis has a narrow rostral edge which projects in a lateral direction.

A second internal aponeurosis is the aponeurosis (3). This band-like aponeurosis lies with its narrow margin on the surface of the muscle; to both surfaces muscle fibres are attached (personal communication). This aponeurosis (3) is connected at its base with aponeurosis (1); aponeurosis (3) is attached to crista (3).

A third internal aponeurosis is the aponeurosis (5). This band-like aponeurosis lies with its narrow margin on the surface of the muscle; to both surfaces muscle fibres are attached (personal communication). The ventral half of aponeurosis (5) is flattened in a rostro-caudal direction, but it has a narrow irregular lateral border which is turned back caudalwards; its dorsal half, which lies in the fossa temporalis caudalis, is narrow and flattened in a medio-lateral direction. Aponeurosis (5) is attached to crista (5) on the lower jaw and runs from the lower jaw in a dorso-caudal direction to within the fossa temporalis caudalis.

A fourth internal aponeurosis is the internal aponeurosis (7). The muscle fibres are attached to the lateral surface, to the medial surface and to the distal end of this aponeurosis. This aponeurosis (7) spreads like a fan in a dorso-caudal direction, so in the direction of the processus zygomaticus. This small aponeurosis (7) is attached on spina (7) on the dorsal surface of the lower jaw.

1b. Musculous attachment. This occurs to the rostral and to the caudal fossa temporalis. The fossa temporalis rostralis is bordered by the sharp crista (4) (the edge in which the temporal and the orbital wall of the cerebral skull meet), by a strong vaulting of that part of the roof of the cerebral skull, by the narrow and flat processus medialis showing on either side the crista medialis and by the strongly projecting crista temporalis, which separates it from the fossa temporalis caudalis. This fossa temporalis caudalis is bordered by the crista temporalis, by the only slightly developed crista (24) and by the quadratum-squamosum joint.

A second area of musculous attachment also occurs on part of the ventral surface of the sharp processus zygomaticus, which projects far lateralwards.

A third area of musculous attachment lies on the lateral surface of the dorsal part of the corpus quadrati just ventrally of the condylus and also on the dorsal part of the basal half of the strongly developed processus orbitalis quadrati; these two places of attachment on the quadratum are separated by the caudal part of the small crista (6), situated on the rostral edge of the lateral surface of the corpus quadrati.

Attachment by means of an internal aponeurosis. The aponeurosis (6) is no doubt an internal aponeurosis, showing the attachment of muscle fibres on its lateral and on its medial surface (personal communication).

Attachment by means of an external aponeurosis. This is found to the lateral surface aponeurosis (2), so an external aponeurosis showing one wall only (personal communication), to the medial surface aponeurosis (4), so also an external aponeurosis showing one wall only, and to the lateral surface aponeurosis (8), also an external aponeurosis, showing one wall only. — The aponeurosis (2) — as is also the case with the internal aponeurosis (6) — is attached to the ventral side of the ligamentum temporale, which is extended over the lateral surface of the muscle.

2a. Surface of the area of attachment. This area of musculous attachment to the bony surface of the lower jaw is probably the area in which the dorsal edge of the lower jaw, which is flattened in a horizontal plane, has rotated into a vertical position.

Crista (1) is short but very strong; it lies on the dorsal edge of the lower jaw and runs obliquely across the dorsal edge of the lower jaw in a caudo-medial direction.

Crista (3) is very short and runs in a latero-ventral direction; it is a laterally directed branch of crista (1) at about half its length.

Crista (5) is less developed than crista (1); it lies somewhat more caudally than crista (1) and runs in about the same direction as crista (1) along the dorsal edge of the lower jaw.

Spina (7) is small; it lies on the medial border of the dorsal surface of the lower jaw, halfway between crista (5) and the rostral knob of the joint of the lower jaw.

2b. Surface of the area of attachment. The fossa temporalis rostralis is deep and broad; it is deepest just rostrally of the crista temporalis and this place of the greatest depth runs parallel to this crista.

The fossa temporalis caudalis is much narrower and shallower.

The processus zygomaticus is flattened in a dorso-rostral ventro-caudal plane, because of the crista temporalis and the crista (6).

The area of attachment on the quadratum is not described; in my opinion it is probably somewhat convex.

The crista (6) to which aponeurosis (6) is attached and which lies on the processus zygomaticus, is short and small.

3. Mutual course of the muscle fibres. The place of attachment on the lower jaw is very small in comparison with that on the cerebral skull.

From the rostral part of the fan-shaped internal aponeurosis (1) muscle fibres, attached to its lateral surface, run to the medial surface of the lateral surface aponeurosis (2) in a caudo-dorsal direction; the distally attached muscle fibres run in a more dorsal direction to the medial surface of the base of aponeurosis (2). The muscle fibres attached to the medial surface of this rostral part of aponeurosis (1) run in a caudo-dorsal direction to the lateral surface of the medial surface aponeurosis (4). — From the somewhat medially curved caudal part of the fan-shaped internal aponeurosis (1) muscle fibres, attached to its lateral surface, run to the medial surface of aponeurosis (6). The muscle fibres, attached to the medial surface of this caudal part, run to the lateral surface of the medial surface aponeurosis (4). — From the plate-shaped part of the internal aponeurosis (1) the muscle fibres attached to its medial surface run to the bony surface of the fossa temporalis rostralis and the muscle fibres, attached to its lateral surface run to the medial surface of surface aponeurosis (8). This lateral surface aponeurosis (8) is attached to the cristae temporalis and medialis.

From the internal aponeurosis (3) the muscle fibres run in caudal, medial and rostral directions, but all to aponeurosis (6).

From the aponeurosis (5) the muscle fibres run to aponeurosis (6), to the dorsal end of the quadratum caudally of crista (6) and to the surface of the fossa temporalis caudalis.

Aponeurosis (6) envelops the internal aponeurosis (3) like a gutter and also the ventral part of aponeurosis (5); the two gutters are separated by a laterally projecting fold of aponeurosis (6).

From the lateral surface of the internal aponeurosis (7) muscle fibres run to the medial surface of aponeurosis (6). From the medial surface of aponeurosis (7) muscle fibres run to the dorsal part of the basal half of the processus orbitalis quadrati and from the distal end of aponeurosis (7) to the ventral surface of the processus zygomaticus and to a small area on the surface of the cerebral skull medio-ventrally of the processus zygomaticus.

From the ventral border of aponeurosis (6) muscle fibres run to the bony surface of the lower jaw.

(H XXV) v. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus adductor mandibulae externus profundus

(Bams, 1956, pp. 248-251; personal communication)

This muscle runs a) from the median surface of the lower jaw, b) to the processus orbitalis of the quadratum. This muscle is divided into two distinctly separated parts, a rostral one and a caudal one; the rostral part is the major and more strongly developed part of the muscle.

1a. Musculous attachment. This occurs with the rostral part of the muscle to an area on the lower jaw along the entire dorsal border of the angulare and complementare where these fused bones border the canalis primordialis; this area of attachment also occupies the flat area ventrally of this border on the lateral surface of the angulare as far as just rostrally of the sunken region (s.r.); the ventral border lies just rostrally of the crista (c.i.). As is stated at another place in the text, this rostral part of the muscle is situated on the lower jaw in the more caudal part of the area of attachment, while a small number of muscle fibres are attached more dorsally over the canalis primordialis to the medial surface of the supra-angulare.

Another area of musculous attachment shows the caudal part of the muscle to a more caudally situated place of attachment, lying between the jaw joint, the lateral upwardly directed edge of the lower jaw; the dorsalward facing flat plane of that part of the lower jaw lying just rostrally of the jaw joint.

Attachment by means of an internal aponeurosis. This is the aponeurosis (XIX) which may be called an internal aponeurosis, judging from its position.

This aponeurosis of the musculus adductor mandibulae internus pterygoideus bears the fibres of this muscle on one surface and some muscle fibres of the musculus adductor mandibulae externus profundus on the opposite surface. These latter fibres are attached secondarily on this aponeurosis and they do not contribute to its formation. This aponeurosis (XIX) inserts caudally on the crista (c.i.).

1b. Musculous attachment. This occurs to the processus orbitalis quadrati. The area of this musculous attachment of the rostral part lies on the dorsal border of the rostral part of the processus orbitalis, caudally of the crista (c.h.); except to this most rostral part no muscle fibres are attached to the dorsal part of the processus orbitalis. The lateral and the medial surface of the processus orbitalis, except the dorsal thickened part, are entirely occupied by muscle fibres of the caudal part of the muscle. The place of attachment is restricted to the processus, so it does not extend upon the corpus ossis quadrati. The lateral surface of the processus orbitalis is not entirely occupied by muscle fibres; apparently there is room to spare at the caudal end, so here the surface of the bone remains bare. On the medial surface the caudal border is defined by the place of attachment of the small aponeurosis (XIII) of the musculus protractor. On the quadratum most muscle fibres are attached rostrally.

Attachment by means of an internal aponeurosis. The aponeurosis (XVIII) is an internal aponeurosis (personal communication). To aponeurosis (XVIII) two kinds of muscle fibres are attached: (1) a layer of muscle fibres which really belong to this aponeurosis; these primary fibres and the following secondary fibres show a clearly demarcated border-plane; (2) muscle fibres which insert secondarily on this aponeurosis and cover it nearly entirely; caudally this layer continues a little beyond aponeurosis (XVIII) and here it is attached musculously to the lateral surface of the processus orbitalis of the quadratum, *viz.* caudally of the crista (c.h.). To this crista (c.h.) the aponeurosis (XVIII) is attached.

Attachment by means of an external aponeurosis. This occurs with aponeurosis (2), which is no doubt an external aponeurosis (personal communication). In some cases this aponeurosis (2) is found as a slightly developed aponeurosis. It lies on the lateral surface of the muscle at the most caudal place of attachment.

2a. Surface of the area of attachment. This area of musculous attachment is probably an accidented area; the dorsalward facing plane of the lower jaw is flat.

The crista (c.i.) is a crista.

2b. Surface of the area of attachment. The median surface of the processus orbitalis quadrati is excavated. The crista (c.h.) to which the fibres of aponeurosis (XVIII) are attached, is a firm crista; it is formed by the broadened and somewhat thickened border of the rostral end of the processus orbitalis quadrati which end is flattened in a horizontal plane.

The place of attachment of aponeurosis (2) shows no differentiation of the surface of the bone.

3. Mutual course of the muscle fibres. The muscle fibres converge markedly though very gradually towards the quadratum. The rostral part of the muscle is very thin at its ventral side, as the attachment is musculous and the place of attachment very narrow.

(H XXV) vi. *Ondatra zibethica* (L.) (Rodentia; Mammalia)

a. Musculus masseter II

(Van Vendeloo, 1953, pp. 122-126; personal communication)

This strong and thick muscle runs a) from the lateral surface of the lower jaw, b) to the ventral surface of the zygomatic arch.

1a. Musculous attachment. This occurs at a number of small areas of attachment.

A first area of musculous attachment lies on the lateral surface of the lower jaw, where the muscle fibres are attached musculously between the line (1), the crista (8) and the costa (1); the dorsal border of this place of attachment lies about $^{1}/_{2}$ cm dorsally of the crista (1) (the line (1) is about 1 cm long, runs caudo-dorsalwards and commences at the point where the cristae (8) and (9) meet; the very small crista (8) is directed rostralwards; the costa (1) lies on the lateral surface of the processus angularis; it runs dorso-ventrally, ventrally it curves rostralwards).

A second area of musculous attachment occurs on the lateral surface of the processus angularis caudo-ventrally of the crista (7) and caudally of the costa (1); a great number of muscle fibres are attached here (the crista (7) lies along the rostro-dorsal edge of the processus angularis of the lower jaw).

A third area of musculous attachment occurs on the medial surface of the caudal part of the processus angularis; a great number of muscle fibres are attached here.

A fourth area of musculous attachment lies on the lateral surface of the lower jaw between the crista (9) (lying rostrally) and the ventral part of the furrow-shaped fossa (3); to it a great number of muscle fibres are attached; the dorsal border of this place of attachment runs from the point where the crista (8), directed rostralwards, and the crista (9), lying rostrally, meet almost horizontally rostralwards.

Attachment by means of an internal aponeurosis. The aponeurosis (D) is an internal aponeurosis (personal communication), as muscle fibres are attached to both surfaces. In the most rostral part the muscle fibres are slantingly attached in small numbers to its lateral and medial surfaces. To the most caudal part a great number of muscle fibres are slantingly attached to its lateral and medial surfaces. The aponeurosis (D) has a maximal length of 9 mm, its most rostral part and its most caudal part are both about $3^{1}/_{2}$ mm long. Its form is irregular. The rostral part of the aponeurosis is flat. The lateral surface of the caudal part is concave, the medial surface is convex. The aponeurosis (D) is attached to the crista (7) (lying along the rostro-dorsal edge of the processus angularis of the lower jaw), the costa (1) and the rostralwards directed crista (8).

Another attachment by means of an internal aponeurosis occurs with aponeurosis (F). The dorsal part of the aponeurosis (F) is internal; the ventral part is external (personal communication). In the rostral part the aponeurosis lies superficially on the ventral side; dorsally it is covered by muscle fibres attached slantingly to its lateral surface. The medial surface is also entirely covered by muscle fibres attached slantingly to it. In the caudal part the muscle fibres are slantingly attached to the lateral surface only, except the most ventral margin, which is entirely free of muscle fibres. The most rostral part of aponeurosis (F) is about 13 mm long, its very thin caudal part, which is about 4 mm broad, is about $1^{1}/_{2}$ mm long. Aponeurosis (F) is attached to the rostrally lying crista (9) and to the line (1).

1b. Musculous attachment. This occurs to the zygomatic arch with a great number of muscle fibres between the cristae (3) and (5). The crista (3) forms the ventral surface of the zygomatic arch, lying more laterally, if there is still a second or a second and third crista (in the rostral part of this ventral surface this is the crista (10), and in the middle part the crista (4); in the caudal part we find the cristae (4) and (5)).

Attachment by means of an internal aponeurosis. The aponeurosis (E) is an internal aponeurosis, as muscle fibres are found on the lateral and on the medial surface (personal communication). The muscle fibres are slantingly attached to the entire lateral surface and to the medial surface, except to the most caudal part. The maximal length of the aponeurosis is about 13 mm, rostrally it is about 10 mm and caudally it is about 3 mm long. Aponeurosis (E) is attached to the crista (5) on the zygomatic arch from the point (pE) to the point (pF) (at the point (pE) the crista (5) commences; at the point (pF) the crista (5) joins the crista (4), a fraction of a mm from the point (pD) on the crista (4)). Aponeurosis (E) is situated medially of the aponeurosis (C) and its rostral part is firmly connected with this aponeurosis (C) over a length of about 7 mm.

Attachment by means of an external aponeurosis. This is the aponeurosis (C). This is no doubt an external aponeurosis (personal communication), judging from the fact that it lies superficially and that the muscle fibres are slantingly attached to its medial surface. Aponeurosis (C) has its maximal length of 10 mm in the middle, rostrally and caudally it becomes shorter and diminishes to 0 at the points (pC) and (pD) on the zygomatic arch. Aponeurosis (C) is attached to the crista (3) from the point (pC) (lying far rostralwards) to the point (pD) (lying far caudalwards on the zygomatic arch).

2a. Surface of the area of attachment. The first area of musculous attachment on the lateral surface of the lower jaw is practically flat.

The surface of the second area of musculous attachment on the lateral surface of the processus angularis of the lower jaw, caudally of the costa (1), is convex.

The surface of the third area of musculous attachment on the medial surface of the caudal part of the processus angularis of the lower jaw, is concave.

The surface of the fourth area of musculous attachment on the lateral surface of the lower jaw, is not described in detail.

The costa (1) runs dorso-ventrally, ventrally it curves rostralwards; it has the shape of a costa or of a crista (according to Van Vendeloo, 1953, pp. 276-277 it can be a matter of contention, whether it is a costa or a crista).

The crista (7) lies along the rostro-dorsal edge of the processus angularis of the lower jaw; it has the shape of a crista.

The crista (8) is a very small crista; it is directed rostralwards.

The crista (9) is a high crista.

The line (1) is about 1 cm long, it runs caudo-dorsalwards and commences at the point where the cristae (8) and (9) meet.

2b. Surface of the area of attachment. This surface is formed by a very small elevation (5) on an almost flat bone (between the crista (3) and (4)).

The crista (3), to which the internal aponeurosis (E) as well as the external aponeurosis (C) is attached, is the ventral surface of the zygomatic arch; it lies laterally.

Heading XXVI: musculous + external aponeurosis — musculous + internal aponeurosis + external aponeurosis

(H XXVI) i. *Sphaeroides oblongus* (Bloch) (Plectognathi; Pisces)

a. Musculus dilatator operculi pars medialis

(Sarkar, 1960, pp. 49-51)

This large, fan-shaped muscle runs a) from the whole upper surface of the postfrontale, b) to the spina and the crista (3) of the operculum. This muscle is broad on the dorsal side and narrows ventrally.

1a. Musculous attachment. This occurs dorsally to the postfrontale over a broad area; the area of attachment is about the shape of a circle sector. The border-lines are formed by the lateral edge of the postfrontale, a thin groove between the postfrontale and the squamosum and the semi-circular border of the postfrontale. To this area the muscle is mainly attached musculously as far as the border-line with the praefrontale, except part of the superficial bundles.

Another area of musculous attachment occurs to the anterior surface of the rounded base of the temporal process of a few muscle fibres which, attached to an aponeurosis on the medial top of crista (3), diverge caudo-dorsally.

A t t a c h m e n t b y m e a n s o f a n e x t e r n a l a p o n e u r o s i s. This is the case with the aponeurosis (19), which is a thin surface aponeurosis to which the superficial bundles of the posterior half of the muscle are attached. This aponeurosis (19) is attached to the border-line of the praefrontale. To this aponeurosis (19) lateral muscle fibres are attached which run from the crista (3) towards the posterior part of the postfrontale. This aponeurosis (19) fuses with the aponeurosis (36) of the portion 3 of the musculus supracranialis and is closely attached to the thin connective tissue plate covering the entire dorsal muscles of the head. To this dorsal aponeurosis (19) also run straight dorsally the anterior superficial bundles of the second part of the muscle which are attached to the rostro-dorsal surface of crista (3) of the operculum. To the medial surface of the dorsal aponeurosis (19) run dorsally the posterior fibres of the second part of the muscle which are attached musculously to the caudal surface of crista (3).

1b. M u s c u l o u s a t t a c h m e n t. This occurs with a small bundle of muscle fibres, belonging to the first part of the muscle and attached to the same area on the spina as the aponeurosis (20), which aponeurosis is covered on its lateral surface by the mentioned small bundle of muscle fibres. The formation of the spina, to which the narrowing of the dorsal extreme of the operculum leads, is due to the calcification of the aponeurosis and occurs only in the adult stage of Sphaeroides (p. 107).

A second area of musculous attachment occurs with the (first) part of the muscle to crista (3).

A third area of musculous attachment to the posterior surface of the dorso-lateral crista (3) of the operculum shows part of the second part of the muscle. This ventral attachment of this second part is musculous, except for an internal aponeurosis attached to the medial edge of crista (3).

A fourth area of musculous attachment occurs with the anterior superficial bundles of the second part to the rostro-dorsal surface of crista (3) of the operculum.

A fifth area of musculous attachment shows the posterior fibres of the second part to the caudal surface of crista (3) of the operculum.

A t t a c h m e n t b y m e a n s o f a n i n t e r n a l a p o n e u r o s i s. The partly aponeurotic attachment of the second part of the muscle to the posterior surface of the dorso-lateral crista (3) of the operculum occurs by means of an internal aponeurosis attached to the medial edge of this crista (3). This cannot be observed unless the superficial muscle fibres are removed.

A second place of attachment by means of an internal aponeurosis occurs by means of the aponeurosis (20) which is an internal aponeurosis. This aponeurosis (20), from its ventral attachment, runs dorsally up to the middle of the anterior part of the postfrontale, bending a little rostrally. The angles of attachment of the muscle fibres with the aponeurosis vary from 90°-180° on both sides of the aponeurosis.

A t t a c h m e n t b y m e a n s o f a n e x t e r n a l a p o n e u r o s i s. This aponeurosis we have in mind is in my opinion perhaps an external aponeurosis, judging from the fact that it bears most posterior muscle fibres. To this aponeurosis a few most posterior muscle fibres are attached. This takes place to the medial top of crista (3) ventrally to the dorsal spina.

2a. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. The postfrontale, which is a part of the frontale proper, sinks below the level of the frontale and has a shallow surface.

2b. S u r f a c e o f t h e a r e a o f a t t a c h m e n t. The dorsal spina, to which the ventral attachment of the aponeurosis (20) of the first part of the muscle takes place, shows a short and triangular area of attachment. The spina is a triangular free process above the articulation of the operculum with the hyomandibulare; its pointed end is directed dorso-rostrally towards the squamosal process.

The crista (3) to which the second part of the muscle is attached, has a flat surface directed to the medial side; the area of attachment is also triangular as that on the spina, but it is a little bigger and lies next to the area of attachment on the spina and ventrally to it.

(H XXVI) ii. *Phalacrocorax carbo sinensis* (Shaw & Nodder) (Steganopodes; Aves)

a. Musculus adductor mandibulae internus pseudotemporalis

(DULLEMEIJER, 1951, pp. 254-255; personal communication)

This muscle runs a) from the cerebral skull, close behind the orbita, b) to the canalis primordialis of the lower jaw.

1a. Musculous attachment. This occurs to the oblong area behind the orbita.

Attachment by means of an external aponeurosis. This aponeurosis (E) is an external aponeurosis with a total loss of one of the walls. This far rostralward situated aponeurosis (E) is attached to the crista ventrally of this area of musculous attachment, which runs from the processus postorbitalis caudalwards. The non-parallel muscle fibres start from the medial plane of the aponeurosis.

1b. Musculous attachment. This occurs to the bottom of the canalis primordialis.

Attachment by means of an internal aponeurosis. The attachment to the little crista at the rostro-medial border of the oval fossa of the canalis primordialis takes place by means of an aponeurosis (the lateral aponeurosis called (F)), which at all events more dorsally is an internal aponeurosis.

Attachment by means of an external aponeurosis. A second aponeurosis, the very small, more medial aponeurosis (G), is an external aponeurosis with a total loss of one of the walls, the muscle fibres starting from the lateral plane of the aponeurosis.

2a. Surface of the area of attachment. The surface of this oblong area is almost flat, rostralwards it forms a very small fossa, caudally a little convexity. The mentioned crista seems to be very low.

2b. Surface of the area of attachment. The area on the bottom of the canalis primordialis is an oval fossa.

3. Mutual course of the muscle fibres. The majority of the muscle fibres, at any rate the lateral muscle fibres, run from the area of musculous attachment on the cerebral skull to that in the canalis primordialis. At both ends of the muscle we find an aponeurosis on the medial side. On the lower jaw we find an internal aponeurosis (F): the muscle fibres attached on its lateral surface reach the medial surface of the aponeurosis (E), attached on the cerebral skull. The muscle fibres lying between the aponeuroses (F) and (G) constitute a very narrow muscle, consisting of a flattened bundle, of which the attachment of these muscle fibres at the other end lies on the medial surface of the aponeurosis (E).

b. Musculus protractor quadrati et pterygoidei

(DULLEMEIJER, 1951, pp. 400-402; personal communication)

This muscle runs a) from the ventro-medial surface of the cerebral skull, b) to the medial surface of the quadratum and to the dorsal surface of the pterygoid.

1a. Musculous attachment. This occurs to an area on the ventro-medial surface of the cerebral skull; this area is limited by the medial line of the base of the skull and the line connecting the processus postorbitalis with the squamosum-quadratum joint.

Attachment by means of an external aponeurosis. The attachment to the low lateral crista into which the processus postorbitalis changes ventro-caudally, is aponeurotic; this aponeurosis (K) is a surface aponeurosis (an external aponeurosis with total loss of one of the walls) (personal communication). The attachment to the straight crista which lies close behind the orbitae and which runs medially from the processus postorbitalis, occurs by means of an aponeurosis; the character of this aponeurosis is also that of a surface aponeurosis (personal communication).

1b. Musculous attachment. This occurs to the area on the medial surface of the quadratum; this area lies in the rostral-medial part of the body of the quadratum and covers the sharp, flattened processus orbitalis. The caudal border of this area of musculous attachment is indicated by a very smooth bony line which is too weak to call it a crista. Part of the muscle fibres are attached to a blunt processus on the quadratum. The attachment to the dorsal groove on the pterygoid is musculous.

Attachment by means of an internal aponeurosis. This occurs by means of the internal aponeurosis (L); it is attached to the top of the dorso-medial wing and to the top of the dorso-lateral wing, showing the character of cristae; these wings lie on the pterygoid and continue on the quadratum.

Attachment by means of an external aponeurosis. The attachment to the small crista which runs from the base of the articulation of the quadratum with the pterygoid to the base of the processus orbitalis, takes place by means of a surface aponeurosis (an external aponeurosis with total loss of one of the walls) (personal communication). The attachment to the top of the dorso-medial wing and to the top of the dorso-lateral wing, showing the character of cristae, occurs by means of a short aponeurosis, which is a surface one (an external aponeurosis with total loss of one of the walls) (personal communication); on these cristae the internal aponeurosis (L) is also attached.

2a. Surface of the area of attachment. The area of musculous attachment is trapeziform. The surface of this area is a little uneven; the surface shows two slight depressions separated by a very small bubble. The first-mentioned crista is low; it bends caudad and disappears at about $^3/_4$ of the distance between the processus postorbitalis and the squamosum-quadratum joint.

2b. Surface of the area of attachment. The area of musculous attachment to the quadratum is a little concave. That on the processus orbitalis is probably a flat plane. The processus on the quadratum is blunt. The bottom of the dorsal groove of the pterygoid is probably convex, as the pterygoid in transverse section is round.

3. Mutual course of the muscle fibres. Part of the muscle fibres showing a musculous attachment to the cerebral skull, are attached musculously to the quadratum and to the pterygoid. To the caudal part of this area of the cerebral skull no muscle fibres are attached; the connection of the muscle fibres with the bone of the bulla-shaped area of the cerebral skull takes place by loose tissue. Another part of these muscle fibres showing a musculous attachment to the cerebral skull, are attached to both surfaces of the internal aponeurosis (L) on the dorso-lateral wing of the pterygoid. A number of the muscle fibres arising from the cerebral skull are attached to the short aponeurosis on the top of the medial crista-like wing of the pterygoid; this aponeurosis continues on the bony line of the quadratum. Part of the muscle fibres, at one end attached to aponeurosis (K) on the lateral crista on the cerebral skull, are attached at the other end to the internal aponeurosis (L) on the pterygoid and to its continuation on the small crista

on the quadratum. Another part of these muscle fibres attached to aponeurosis (K) are attached to the pterygoid itself and to the blunt processus on the quadratum.

(H XXVI) iii. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus depressor mandibulae

(Davids, 1952, pp. 92-94)

This muscle as a whole runs a) from the lateral and from the ventral surface of the neurocranium behind the articulatio quadrato-neurocranialis, b) towards the processus angularis posterior of the lower jaw. — This well-developed muscle contains three parts, called "le grand pyramidal", "le muscle triangulaire" and "le muscle carré".

1a. Musculous attachment. This occurs with the part called "le grand pyramidal" on the lateral surface of the neurocranium on an area behind the fossa temporalis and in front of the crista occipitalis and beneath a weak costa; on the ventral side no distinct limit is indicated.

A second area of musculous attachment, now of the part called "le muscle triangulaire" lies on the lateral surface of the neurocranium behind the orificium auditivum externum; the area of attachment occupies the entire lateral surface of the large processus occipitalis lateralis.

A third area of musculous attachment, now of the part called "le muscle carré", as far as its medial part is concerned, lies on the medial surface of the processus occipitalis lateralis and in front of it after having passed costa (21) on the ventral surface of the horizontal osseous thin plate ("lame") which covers the cavum tympanicum beneath.

A fourth area of musculous attachment, now of the part called "le muscle carré", as far as its lateral part is concerned, lies on the lateral surface of the ligamentum neurocranio-mandibulare.

Attachment by means of an external aponeurosis. The part called "le grand pyramidal" is attached by means of the aponeurosis (16) which is probably an external aponeurosis, as it lies at the border of the area of musculous attachment; this aponeurosis (16) is attached to the crista occipitalis.

A second area of aponeurotic attachment, now for the rostral muscle fibres of the part called "le muscle triangulaire", is found on aponeurosis (18) which is probably an external aponeurosis, as it covers the muscle on its inner side; the aponeurosis is attached to the caudal sharp border of the orificium auditivum externum.

A third area of aponeurotic attachment, now for the caudal muscle fibres of the part called "le muscle carré", as far as its medial part is concerned, occurs by means of aponeurosis (22), which is probably an external aponeurosis, as it lies at the border of the area of musculous attachment; this aponeurosis is attached to crista (22).

1b. Musculous attachment. This occurs with the most caudal muscle fibres of the part called "le grand pyramidal" to the medial surface of the processus angularis posterior.

A second area of musculous attachment, now of the part called "le muscle triangulaire", as far as the rostral muscle fibres are concerned, lies on the lateral surface of the processus angularis posterior. The area of this musculous attachment of the rostral muscle fibres lies behind the processus mandibularis externus; the area ends dorsalwards on the dorsal border of the processus angularis posterior and ventralwards at crista (19).

A third area of musculous attachment, now of the part called "le muscle triangulaire", as far as it concerns the caudal muscle fibres, lies on the medial surface of the processus angularis posterior.

A fourth area of attachment, now of the part called "le muscle carré", as far as its medial part is concerned, is found for a part of its muscle fibres on a narrow and very oblong area, lying on the broadened caudal border of the medial surface of the processus angularis internus, extending caudalwards along the ventral border of the processus angularis posterior; thus in front it lies on the interior wall of the cavum mandibulare, lying beneath the articulatio quadrato-mandibulare.

A fifth area of attachment, now of the part called "le muscle carré", as far as it concerns the rostral muscle fibres of the lateral part, is found on the lateral and medial wall of the cavum mandibulare. As far as the more caudal muscle fibres are concerned, they attach on the medial surface of the processus angularis posterior caudalwards of the cavum mandibulare.

Attachment by means of an internal aponeurosis. Attachment of most of the muscle fibres of the part called "le grand pyramidal" occurs on the internal aponeurosis (17), *i.e.* on the medial surface and on the anterior part of the lateral surface of aponeurosis (17), which is attached to the caudal border of the processus angularis posterior.

Attachment by means of an external aponeurosis. Part of the rostral muscle fibres of the part called "le muscle triangulaire" are attached by means of the aponeurosis (19) which is probably an external aponeurosis; this aponeurosis (19) is attached to crista (19); this crista (19) extends archwise from the curvature of the dorsal border of the processus angularis posterior as far as the base of the processus mandibularis externus.

A second area of attachment, now of a part of the rostral muscle fibres of the part called "le muscle triangulaire", occurs by means of an aponeurosis (20) which is probably an external aponeurosis; this aponeurosis (20) is attached to the dorsal border of the processus angularis posterior.

A third area of attachment, now of a large part of the muscle fibres of the part called "le muscle carré", as far as its medial part is concerned, lies on aponeurosis (23), which is probably an external aponeurosis, as it lies at the border of the area of musculous attachment and at the ventral margin of the processus angularis posterior.

2a. Surface of the area of attachment. The area of the part called "le grand pyramidal" on the neurocranium shows the positive vault of the cerebral capsule.

2b. Surface of the area of attachment. No detailed description is given.

3. Mutual course of the muscle fibres. The muscle fibres of the part called "le grand pyramidal" converge downwards.

The aponeurosis (17) runs parallel to aponeurosis (16) and on its lateral side.

The rostral muscle fibres of the part called "le muscle triangulaire", lying behind the quadratum, diverge fan-like.

The rostral muscle fibres of the lateral part of the "muscle carré" run mainly in a horizontal direction; the more caudal muscle fibres run more and more ventralwards.

(H XXVI) iv. *Phasianus colchicus* L. (Galli; Aves)

a. Musculus adductor mandibulae posterior

(FUCHS, 1954, pp. 454-458; personal communication)

This not strongly developed muscle runs a) from the lateral surface of the quadratum, b) to the lateral surface of the lower jaw. It runs in a rostro-latero-ventral direction.

1a. Musculous attachment. This occurs on a triangular area on the lateral surface of the quadratum, lying on the lateral surface of the corpus quadrati, on the processus orbitalis quadrati and partly also on the processus articularis quadrati. This area of attachment is bordered on its dorsal side by a generally strongly developed crista (12), there are no cristae on its other sides.

Attachment by means of an external aponeurosis. The strongly developed aponeurosis (12) is a surface aponeurosis (so an external aponeurosis), offering a large area of attachment, to which muscle fibres are attached on the medial surface only. In some cases a small muscle bundle connecting the musculus adductor mandibulae externus with the musculus adductor mandibulae posterior is attached to the lateral surface of this aponeurosis (in that case the aponeurosis (12) is an internal one; see Heading XIII no. ii. a). The greatest length of this aponeurosis varies to maximally 9.5 mm.

1b. Musculous attachment. This occurs to an area on the lateral surface of the lower jaw bordered caudally by the processus mandibularis externus (bearing on its rostral part the often hardly distinguishable very short crista (11)) and the lateral part (A′) of the articulation surface for the quadratum, bordered rostrally by crista (7), crista (7′) and spina (1), (3), bordered on its "dorsal" side by the margin of the lower jaw and bordered ventrally either entirely by the groove (su.) or partly by the slightly developed crista (13).

Attachment by means of an internal aponeurosis. This is the aponeurosis (11), which in a few cases is partly a lateral surface aponeurosis (in these few cases the area of attachment is very small; personal communication). The aponeurosis (11) is exceedingly small: about 1 mm broad and about 6 mm long.

Attachment by means of an external aponeurosis. This is the case with the lateral surface aponeurosis (13), so with an external aponeurosis of which only one wall is present (personal communication). This aponeurosis is rather strongly developed; aponeurosis (13) is connected with aponeurosis (9) at the point where crista (7) meets the groove (su.).

2a. Surface of the area of attachment. The aponeurosis (12) is for the greater part attached to crista (12); at the caudal end, however, the place of attachment is not marked by any special structure of the bony surface. The crista (12) on the rostro-lateral surface of the processus orbitalis quadrati, sometimes extending on the lateral surface of the corpus quadrati for the attachment of aponeurosis (12), is a generally rather strongly developed crista.

2b. Surface of the area of attachment. Crista (11) and (13) have the shape of a crista. Crista (13) is absent in a number of specimens.

3. Mutual course of the muscle fibres. The muscle fibres are profuse along the dorsal side of the area of attachment on the quadratum, so ventrally of crista (12); ventralwards the muscle fibres are gradually less densely implanted.

The implantation of the muscle fibres on the "broadened" dorsal border of the lower jaw is a little denser than on the lateral side of the lower jaw.

b. Musculus depressor mandibulae

(Fuchs, 1954, pp. 669-672; personal communication)

This muscle runs a) from the processus angularis internus and the processus retro-articularis of the lower jaw, in a dorso-caudal direction, b) to the cerebral skull. This very strongly developed muscle is situated caudally of the jaw joint.

1a. Musculous attachment. This occurs to the medial surface of the processus retro-articularis and on the caudal surface of the processus angularis internus.

Attachment by means of an external aponeurosis. For the greater part the attachment takes place by means of the surface aponeurosis (21) which is situated ventrally and partly also laterally of the musculus depressor mandibulae; this aponeurosis is strongly developed; it is attached to crista (21a) and (21b). This external aponeurosis (21) shows only one wall; it spreads over the processus retro-articularis in a curious way (personal communication).

1b. Musculous attachment. This occurs to the narrow lateral surface of the occipital wing, which borders the cavum tympani on its caudal side.

Attachment by means of an internal aponeurosis. This takes place by means of the ligamentum neurocranio-mandibulare (see also Fuchs, 1955, pp. 116, 120; Burggraaf & Fuchs, 1955, p. 98) to crista (22a) and (22b). This ligamentum only partly answers to the definition of a ligamentum and serves as an aponeurosis. This is especially the case with the shorter middle part of the distal end which shows three separate parts. This middle part ends freely in a triangular "lobe". Only to this triangular "lobe" the muscle fibres are attached to both sides.

Attachment by means of an external aponeurosis. For the greater part the ligamentum neurocranio-mandibulare is a medial surface aponeurosis (aponeurosis (22)).

2a. Surface of the area of attachment. The area of musculous attachment on the medial surface of the processus retro-articularis is probably a rather flat plane.

The area of musculous attachment on the caudal surface of the processus angularis internus bears the crista η; on either side of this crista is the area of musculous attachment.

Crista (21a) and (21b) are found on the dorsal and the ventral edge of the processus retro-articularis.

2b. Surface of the area of attachment. The area of musculous attachment on the lateral surface of the occipital wing is probably flat.

The crista (22a) and (22b) are typical cristae.

(H XXVI) v. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus adductor mandibulae externus et posterior

(Bams, 1956, pp. 89-91, 92-101; personal communication)

This complex muscle runs a) from the fossa temporalis and adjacent parts as the crista occipitalis, the knob on the squamosum, *etc.*, b) to the dorsal and lateral surface of the lower jaw. This complex muscle is situated on the lateral side of the skull between the eye and the occipital region at one end and the lower jaw at the other end.

1a. Musculous attachment. This occurs to the entire bony surface of the fossa temporalis; only the rostro-ventral, flat and vertical part of its bottom is free from it. This is where the aponeurosis (III) lies closely against the surface of the bone. This fossa temporalis is situated between the expansion of the neurocranium at the level of the caudal end of the telencephalon and the more caudal expansion of the cerebral skull constituted by the projecting complex of bones containing a.o. the internal ear. — The fossa temporalis is bordered caudo-dorsally by the part (c.c.) of the crista occipitalis; in its more horizontal part it is bordered ventrally by the crista (c.a.) of the regio deltoides (this crista (c.a.) ends on the knob of the squamosum which bears the fossa glenoidalis); it is bordered rostro-dorsally by the crista posttemporalis, a low but sharply marked edge, which ends on the processus temporalis; from the processus temporalis ventralwards runs a weakly developed crista (c.e.) which runs on the bottom of the fossa temporalis to the knob on the squamosum; it is bordered dorsally by the weakly developed crista medialis which separates the right and left fossae temporales.

Attachment by means of an external aponeurosis. The aponeurosis (IV) is entirely an external aponeurosis, showing one wall only (personal communication). This external aponeurosis (IV) is a lateral surface aponeurosis. This aponeurosis lies quite rostral and dorsal; it is attached to the processus temporalis and more rostrally along the crista posterior. The edges of the aponeuroses (IV) and (VIII) constitute a strand of more dense connective tissue; this strand runs from the processus temporalis ventralwards, bends at right angles in a caudal direction and attaches to the knob of the squamosum. Aponeurosis (IV) is inseparably fused at its dorsal side with aponeurosis (VI) of the musculus adductor mandibulae pseudotemporalis.

The aponeurosis (VIII) is entirely an external aponeurosis, showing one wall only (personal communication). This external aponeurosis (VIII) is a lateral surface aponeurosis, which is entirely "superficial" (p. 96). This aponeurosis (VIII) lies on the lateral side of aponeuroses (XII) and (XIV) and quite caudally. This aponeurosis is small and not very strongly developed. It is attached to the knob of the squamosum; the attachment does not occupy the sharp ventro-lateral edge of the knob, but lies on the entirely flat area just dorsally of it along a certain line. The aponeurosis (VIII) runs in a rostral direction; its dorsal border is horizontal while its fibres spread out fan-like on the ventral side. The position of this horizontal line is exactly in the direction of the longitudinal axis of the aponeurosis and so its fibres do not insert side by side but one behind the other (the dorsal fibres are attached caudally, the ventral ones farther rostralwards). The ventral border of this aponeurosis lies against the strongly developed aponeurosis (XIV), which ventrally of this border lies freely on the surface but dorsalwords disappears under aponeurosis (IV).

The aponeurosis (X) is entirely an external aponeurosis, showing one wall only (personal communication). The aponeurosis (X) is a medial surface aponeurosis (personal communication); it lies quite medially and caudally, no muscle fibres being attached in or on the caudal surface. The aponeurosis (X) is generally weakly developed; it is attached to the small and weak crista (c.e.) which borders the fossa temporalis on the rostro-ventral side. This aponeurosis effects that the fossa temporalis continues at the same depth in a rostral direction, though the wall of the skull curves medialwards at this place so that in the absence of the aponeurosis the depth would increase. The extension of aponeurosis (X) is not confined to the fossa temporalis. Especially in individuals in which it is strongly developed, the rostral part is rather extended, *viz.* rostrally of the processus temporalis. At this place the aponeurosis (X) is attached along the crista postorbitalis; this extension may amount to several mm. With this is correlated a greater extension of aponeurosis (V).

The aponeurosis (XII) is entirely an external aponeurosis, bearing muscle fibres on its medial surface (personal communication). The muscle fibres lying caudally on the lateral side of the aponeurosis (XII) are not attached to aponeurosis (XII), but are attached to aponeurosis (VIII) (personal communication). Thus the caudo-dorsal part of the aponeurosis (XII) is not superficial; the rostro-ventral part of aponeurosis (XII) covers the lateral surface of the head. This aponeurosis (XII) inserts round the rostral end of the knob of the squamosum as a thick and firm tendon. The aponeurosis (XII) extends in a very inclined position from an extremely caudal point very far rostralwards. Near the place where aponeurosis (XII) reaches the jugale it spreads fan-like and the very long aponeurose-fibres run rostralwards as far as ventrally of the eye. The ventral border remains just medially of the jugale. This ventral border of the aponeurosis is rather sharply demarcated. The aponeurosis (XII) lies dorsally of aponeurosis (XIV) which is less strongly developed than aponeurosis (XII). Ventralwards it passes into aponeurosis (XIV).

The aponeurosis (XIV) is entirely an external aponeurosis showing one wall only (personal communication). This aponeurosis is a strongly developed surface aponeurosis; the muscle fibres are attached in the medial surface. The ventral part of the aponeurosis covers the lateral surface of the head; the dorsal part of the caudally situated aponeurosis (XIV) is not superficial. This aponeurosis in the proper sense of the word is attached to the weak crista (c.g.) of the quadratum, thus close to the turning-point. The aponeurosis is directed rostro-ventralwards.

The plate of connective tissue, called aponeurosis (XXVI) which is hardly discernible, could also be a sheet of connective tissue belonging to the crista which enables the muscle to build up higher than the height of the crista (personal communication). This "aponeurosis" (XXVI) is "formed" by the most external fibres of the caudo-dorsal part of the musculus adductor mandibulae externus together with the most external fibres of the musculus depressor mandibulae. This "aponeurosis" (XXVI) is directed about perpendicularly to the surface of the skull and attaches to the cristae (c.a.) and (c.c.).

1b. Musculous attachment. This occurs to the lower jaw rostrally of the region bearing the cavitas glenoidalis for the quadratum. There is space on the dorsal edge of the lower jaw available for musculous attachment of muscle fibres, as the line of attachment of aponeurosis (V) on the lower jaw runs obliquely rostro-lateralwards.

Attachment by means of an internal aponeurosis. This occurs with the internal aponeurosis (III) (personal communication); it lies more or less deeply in the muscle tissue. This internal aponeurosis lies in the fossa temporalis. This internal aponeurosis (III) is long, broad and thin. It is attached to the knob (R) on the lower jaw; the other end is situated in the fossa temporalis. The aponeurosis has its greatest thickness at the side directed towards the skull, owing to the course of the aponeurose-fibres. In a rostro-ventral direction the aponeurosis becomes more and more narrow and thicker and thereby the surface for the attachment of muscle fibres diminishes. At the place of attachment the aponeurosis could better be called a tendon (or a "stalk"?). — The longitudinal axis of the aponeurosis is curved, running in a dorso-caudo-medial direction at the dorsal end and entirely latero-rostro-ventralwards near the point of attachment. The aponeurosis is curved parallel to the surface of the skull in the fossa temporalis. There is a torsion in the plane of the aponeurosis, amounting to $\pm 90°$ between the dorso-caudal end and the ventro-lateral end of the flat aponeurosis. Because of this torsion the plane of the aponeurosis is situated perpendicularly to the surface of the skull in the fossa temporalis and parallel to the surface close caudally to the orbita. The position of this aponeurosis (III) is in the middle with rostrally and dorsally the wing (V) and caudally the extension (VII).

A second internal aponeurosis is the internal aponeurosis (V) (personal communication). This aponeurosis lies more or less deeply in the muscle tissue. This aponeurosis (V) projects as a dorsally directed wing on the ventral part of the aponeurosis (III) in the shape of a wing; this begins a little rostro-ventrally of the point where aponeurosis (III) enters the fossa temporalis and so a little rostrally of the line of attachment of aponeurosis (X). The plane of this wing-like aponeurosis (V) is directed exactly vertically and dorsalwards. The most rostral part of aponeurosis (V) runs close caudally of the eye and so it is situated farther rostralwards than the place of attachment of aponeurosis (III); consequently this part of aponeurosis (V) is attached separately to the lower jaw at an angle of nearly 90°. The muscle fibres which are attached in aponeurosis (V) run from its lateral surface to aponeurosis (IV) and from its medial surface to aponeurosis (X).

A third internal aponeurosis is the internal aponeurosis (VII) (personal communication). This aponeurosis lies more or less deeply in the muscle tissue. The aponeurosis (VII) is a large aponeurosis-sheet of a great number of tendons, which are all more or less flattened and connected with each other, showing mutual connections. It lies caudally of the strong tendon (III) and parallel to it; the most caudal of these tendons runs closely rostrally of the cavitas glenoidalis for the quadratum. This aponeurosis-sheet (VII) is attached to the sharp dorsal edge of the lower jaw, the most caudal part, however, being attached to the weakly developed small crista (c.f.) (this runs from the upper border of the lower jaw straight latero-ventralwards as far as the dorsal border of the foramen where the ramus mandibularis trigemini V.3. enters the lower jaw).

Attachment by means of an external aponeurosis. An external aponeurosis is found with aponeurosis (IX); it bears muscle fibres on the lateral side only (personal communication). The aponeurosis (IX) is weakly developed. It disappears in a cartilaginous knob on the border of dentale and supraangulare. This aponeurosis (IX) is the most rostral in position; its position is quite rostral.

2a. Surface of the area of attachment. The fossa temporalis is a rather deep excavation of the lateral surface of the skull; the surface of the bone in the fossa temporalis is rough and does not present any cristae or fossae; its function is a musculous attachment.

The knob of the squamosum shows a sharp, ventro-lateral edge and an entirely flat area just dorsally of it; the aponeuroses (VIII) and (XII) are attached to it.

The shape of the processus temporalis of the crista posterior, to which the aponeurosis (IV) is attached, is not described in detail.

The crista (c.e.) is weak; it bears the attachment of the aponeurosis (X).

The crista postorbitalis, along which the aponeurosis (X) is attached, is not described in detail.

The crista (c.g.) of the quadratum is weak; it bears the attachment of the aponeurosis (XIV).

The crista (c.a.) of the regio deltoides and (c.c.) of the crista occipitalis which are not described in detail, bear the attachment of the "aponeurosis" (XXVI).

2b. Surface of the area of attachment. The surface of the bone in the area of attachment on the lateral surface of the lower jaw is in no way visibly differentiated. A well-developed periosteum is present in this case. This is in contrast with places of musculous attachment, where the angle between the muscle fibres and the bony surface is much more obtuse.

The knob (R) on the skeletal lower jaw, and the rest of the place of attachment to which the tendon-like aponeurosis (III) is attached, is not described.

The character of the surface of the place of attachment of aponeurosis (V) to the lower jaw is not described.

The dorsal edge of the lower jaw to which the aponeurosis-sheet (VII) is attached is sharp and the crista (c.f.), to which the most caudal part of this aponeurosis-sheet (VII) is attached, is weakly developed and small.

The cartilaginous knob on the border of dentale and supraangulare in which the aponeurosis (IX) disappears, is triangular and small.

3. Mutual course of the muscle fibres. The direction of the muscle fibres is everywhere in close connection with that of adjacent muscle elements and a cross-cross situation of muscle layers is nowhere marked.

Separation into independent muscles is impossible. Also a separation starting from one definite aponeurosis gives no natural boundary planes, because the fibres from the borders of such a branch generally attach to a place belonging to the attachment area of an adjacent branch. So neither definite branches nor sharply separated areas of attachment occur in this complex muscle; the parts constitute one great continuous complex. Within this complex it is possibe to distinguish groups of muscle fibres, as we will see later on.

The direction of the great many muscle fibres, running between the aponeuroses (V) and (IV) with (X), is the same as that of muscle fibres coming from the fossa temporalis. Gradually the direction changes, however, into a more vertical one; so the fibres from the most rostral part of aponeurosis (IV) are much more favourably situated in relation to the closing of the bill than the more caudal ones.

The direction of the muscle fibres in the ventral part of the muscle which lies in the fossa temporalis and in the continuation of this fossa by aponeurosis (X), passes gradually and without any natural demarcation into the direction of the group of muscle fibres attached to aponeurosis (VIII). So they also generally run from caudo-dorsal to rostro-ventral.

The muscle fibres coming from aponeurosis (VIII) do not attach in aponeurosis (XII), but pass over it (the most ventral part of this aponeurosis (VIII) covers the dorsal part of the proximal part of the stronger aponeurosis (XII)); their direction becomes somewhat less inclined and the muscle fibres run to a number of aponeuroses attached to the lower jaw and to the lower jaw itself. So these fibres make a very acute angle with the longitudinal axis of the lower jaw. The muscle tissue attached to aponeurosis (XII) is not separated from muscle fibres coming from aponeurosis (VIII): quite rostrally the muscle fibres run about horizontally; this direction becomes gradually steeper as the muscle fibres lie more caudalwards.

A transition of one muscle bundle into more than one muscle bundles is shown by a muscle bundle attached to aponeurosis (XII) and one coming from aponeurosis (VIII).

The muscle is curved in three respects: the first curvature is due to a curve in the superficial muscle fibres, the second one is due to a curve in the aponeurosis (III) and the third one to a torsion of this aponeurosis (III). The first curve entails that the outer surface of the belly is convexly curved perpendicularly to the longitudinal axis of the muscle. Because of this curve in the superficial muscle fibres these muscle fibres are able to attach about perpendicularly to the favourably inclined surface of the skull. The more internally situated muscle fibres follow the line of this contour and so they too are curved. — The second curve, that of the aponeurosis (III) (from latero-rostro-ventral to caudo-medio-dorsal), which makes an angle of 0°-45° with the line of action of the resultant of the effective forces involved, entails that the dorsal part of the muscle must act, so to say, "round the corner", which is made possible by the fact that, though in the dorsal part of the fossa temporalis an about equal number of muscle fibres lies on either side of aponeurosis (III), more ventrally the aponeurosis shifts to rostralwards of the median of the fossa temporalis and that the aponeurosis lies directly against the wall of the neurocranium. On the caudal side the number of muscle fibres per surface-unit remains the same as in the dorsal part, but on the rostral side this number markedly decreases, so that at the level of the line processus temporalis-knob on the squamosum, the aponeurosis bears on its rostral surface only superficial fibres, while its caudal surface is still entirely covered by muscle fibres. Owing to this arrangement the curve is maintained during the contraction of the muscle fibres. — In the third place there is a torsion of the aponeurosis (III).

This muscle is no poly-pinnate muscle in the sense of the muscle in *Phalacrocorax* DULLEMEIJER has described as such.

There is a pinnate part of the muscle lying in the fossa temporalis which extends dorso-caudalwards beyond the region of the fossa temporalis; here the muscle fibres do not insert on the crista occipitalis only, but a large number of them pass beyond the crista and end in a layer of entangled and firm connective tissue lying on the aponeurosis of the musculus rectus capitis complexus. Between the right and left muscles this connective tissue forms a weakly developed vertically directed small plate in the median plane on either side of which also muscle fibres are attached (no ossification in this little sheet has been observed as has been found in *Phalacrocorax*).

A number of categories of groups of muscle fibres can be distinguished in this muscle in *Podiceps* now under discussion.

a) groups of muscle fibres which at all events have a surface aponeurosis on one side. This type of muscle has sometimes been called uni-pinnate but this type is not fundamentally different from the fusiform type. This category is found in most groups of muscle fibres. We collect here all the cases in which there is no question either of a feather-like structure or of alternation of the aponeuroses:

(i) groups of muscle fibres which also have a surface aponeurosis at the other end; this second aponeurosis lies opposite the first one; the two aponeuroses run in opposite directions. This category showing an aponeurotic attachment at both ends, is seldom or never pure (a small number of muscle fibres give it the character of the groups b). An example of this group (i) seems to be the group of muscle fibres which come from aponeurosis (X) (which is a medial surface aponeurosis) and run to aponeurosis (V) (which is an internal aponeurosis).

(ii) groups of muscle fibres which have a musculous attachment at the other end. An example of this group (ii) seems to be the group of muscle fibres attached in the medial surface of aponeurosis (III) which come from the fossa temporalis where they are musculously attached; the group of muscle fibres attached in the proximal part of aponeurosis (X) which run to the dorsal edge of the lower jaw where they are musculously attached.

(iii) groups of muscle fibres which, at the first-mentioned aponeurotic end, have an attachment which is also partly musculous and an aponeurotic attachment at the other end. This occurs with the group of muscle fibres attached in aponeurosis (XIV); these muscle fibres mainly attach in the aponeurotic sheet (VII) at the opposite and for a small part to the caudal part of the large area of attachment on the lateral surface of the lower jaw (this area occupies a considerable part of the lateral surface of the lower jaw; it is the continuation of the flat aponeurotic sheet (VII); the aponeurotic sheet (VII) demarcates its caudal border; rostralwards the area extends to about the level of the line of attachment of aponeurosis (IX).

(iv) groups of muscle fibres which at the first-mentioned aponeurotic end, have an attachment which is also partly musculous and a musculous attachment at the other end. The musculous attachments are more considerable at one end than at the other.

(v) groups of muscle fibres which show at least one aponeurotic attachment; at this or at the other end they show an attachment to more than one aponeurosis. An example of this group (v) seems to be the group of muscle fibres attached in aponeurosis (IV) which insert in the lateral surface of the aponeurosis (III), while the more rostrally situated ones end in aponeurosis (V); a second example seems to be the group of muscle fibres coming from aponeurosis (VIII) which run to a number of aponeuroses attached to the lower jaw, and also to the lower jaw itself; these muscle fibres are attached partly in the most rostral part of the broad aponeurotic sheet (VII), partly in the most ventral parts of aponeuroses (III) and (V), for a small part musculously to the edge of the lower jaw and for the rest in aponeurosis (IX).

(vi) groups of muscle fibres which show at least one aponeurosis which collects the muscle fibres of more than one muscle bundle.

Cases like this entail that the aponeuroses belonging to the same muscle part are not equally strong.

b) groups of muscle fibres which show a certain pinnate arrangement owing to the fact that a small number of muscle fibres are attached secondarily to several aponeuroses.

c) groups of muscle fibres which show a proper pinnate arrangement at one end only. There is a pinnate arrangement at this one end, owing to an internal aponeurosis. There is no alternation of aponeuroses, as the opposite end does not show aponeuroses. This category occurs with the group of muscle fibres attached to the internal aponeurosis (III).

d) groups of muscle fibres which show pinnation as well as alternation. This occurs with the internal aponeurosis (V) which alternates with the aponeuroses (IV) and (X), to which the muscle fibres of the lateral surface *resp.* of the medial surface of aponeurosis (V) are attached; the great many muscle fibres between the aponeuroses (V) and (IV) with (X) are nowhere attached directly to the skeleton.

Heading XXVII: internal aponeurosis + external aponeurosis — musculous + internal aponeurosis + external aponeurosis

No examples of muscles lying entirely within the head and attached at both ends to the skull, are given in the literature mentioned.

Heading XXVIII: musculous + internal aponeurosis + external aponeurosis — musculous + internal aponeurosis + external aponeurosis

(H XXVIII) i. *Phalacrocorax carbo sinensis* (Shaw & Nodder) (Steganopodes; Aves)

a. Musculus adductor mandibulae externus superficialis

(DULLEMEIJER, 1951, pp. 249-253; personal communication)

This muscle runs a) from the dorso-lateral area of the temporal region, b) to the lower jaw.

1a. Musculous attachment. This occurs to the dorso-lateral area of the temporal region, and to the whole area of a deep fossa in which the crista temporalis arises, running in a latero-ventral to caudo-dorsal direction, at any rate in the upper part, dorsally as far up as to the cristae, formed at each side by the sharp edges of the processus medialis lying on the dorsal top of the cerebral skull, whereas in the lower part of the fossa the muscle is connected with the bone by loose tissue.

In the second place there occurs a musculous attachment to a narrow area between two horizontal cristae (a dorsal one and a small ventral one), running from the processus temporalis in a rostral direction to the processus postorbitalis.

Attachment by means of an internal aponeurosis. This occurs with the caudal aponeurosis (B) which is attached to the top of the medial crista of the os accessorium and extends its attachment to the top of the crista temporalis.

A second aponeurotic attachment takes place by means of the very short rostral aponeurosis (D); this internal aponeurosis is attached to the top of the processus temporalis.

Attachment by means of an external aponeurosis. This is found in the following four places. It occurs with the external aponeurosis formed by an extended connective tissue plate, extended between the os accessorium and the crista occipitalis, which runs parallel to the crista temporalis. In the second place it occurs with the short surface aponeurosis, which is attached to the processus posttemporalis, to the top of the lateral sharp crista of the processus medialis and its continuation on the ossiculum accessorium as far as its most caudal point. In the third place it occurs with the surface aponeuroses which are attached to the edges of the os accessorium. In the fourth place it occurs with the short surface aponeuroses attached to two horizontal cristae, running from the processus temporalis in a rostral direction to the processus postorbitalis. In my opinion these four aponeuroses are external aponeuroses with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeuroses.

1b. Musculous attachment. This occurs with the dorsal quarter of the upper side of the vertical plate which is the shape of the lower jaw in this region, rostrally of the joint.

Attachment by means of an internal aponeurosis. This occurs by means of the caudal aponeurosis (A) which arises as a tendon, but spreads as a conical aponeurosis which runs caudo-dorsalwards and which is attached to the caudo-lateral part of the oval crista. In the second place it occurs by means of the rostral aponeurosis (C) which is attached as a tendon to the rostral part of the oval crista of the lower jaw; these tendons extending as aponeuroses towards the centre of the muscle are internal aponeuroses (personal communication).

Attachment by means of an external aponeurosis. In my opinion this occurs through the thin aponeurosis which is attached to the slight crista which runs along the latero-ventral border of the area of musculous attachment; this thin aponeurosis is in my opinion an external aponeurosis with a total loss of one of the walls, the muscle fibres starting from one plane of the aponeurosis.

2a. Surface of the area of attachment. The surface of the deep fossa in the dorso-lateral area of the temporal region in which the crista temporalis arises, is concave (personal communication). The narrow area between the two horizontal cristae is only a few mms broad. The crista temporalis is about three times higher than the crista occipitalis. The processus temporalis is a sharp processus which lies on the convex cerebral skull and which is directed caudo-ventralwards and a little lateralwards.

2b. Surface of the area of attachment. The area for musculous attachment on the vertical plate of the lower jaw is a convex surface lying at the bottom of a depression. The top of the rather strong oval crista on the dorsal surface of the lower jaw shows an irregular surface; upon the lateral slight crista two strong tendons are attached.

3. Mutual course of the muscle fibres. This course is partly determined by the fact that the central portion of the muscle consists of a system of a number of feather-shaped units lying in juxtaposition parallel to each other. In this portion of the muscle the internal aponeuroses are attached to the two opposite surfaces of attachment (two to the temporal region of the cerebral skull and two to the lower jaw), forming a system of side-scenes and showing an alternation of the aponeuroses (see also DULLEMEIJER, 1952, p. 96). In this muscle we find four internal aponeuroses, the distances between these aponeuroses being about equal. Part of the muscle fibres run from one internal aponeurosis to the other, forming interrupted zigzag lines. This muscle is not covered at both ends by an external aponeurosis. This is the reason that at both ends of the muscle the muscle fibres starting from the internal aponeuroses run to the skull, *etc.* Thus at the caudal end of the muscle we find muscle fibres running to the most caudal point of the os accessorium where they are attached partially musculously to the os accessorium and partially to the connective tissue and to the surface aponeuroses which are attached to the edges of the os accessorium. At the rostral end of the muscle we find muscle fibres running to the lower jaw; their number is high, as this most rostral aponeurosis is short and small which entails that the area of attachment of a large number of muscle fibres is transferred to the surface of the cerebral skull. As to the portion of the muscle limited by the planes of the two terminal aponeuroses and their produced parts, we also find within this space muscle fibres running to the skeleton and to other aponeuroses, as *e.g.* to the bone of the cerebral skull, to the medial crista and its aponeurosis, to the bone of the lower jaw, *etc.* Thus almost every muscle fibre, arising from the area between the two horizontal cristae lying between the processus temporalis and the processus postorbitalis,

is attached to the internal aponeurosis (C); these muscle fibres show a parallel course and form a flattened bundle (perhaps the remark on the parallel course of the muscle fibres in the rostral part of the musculus adductor mandibulae externus refers to this muscle bundle; see DULLEMEIJER, 1952, p. 95).

(H XXVIII) ii. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus adductor mandibulae externus

(DAVIDS, 1952, pp. 83-86)

This muscle runs a) from the fossa temporalis and the ventral surface of the processus postorbitalis in a rostro-ventral direction, b) to the lateral surface of the lower jaw in front of the processus coronoideus.

1a. Musculous attachment. This occurs to a large part of the fossa temporalis and the ventral surface of the processus postorbitalis; this surface lies between crista (1) and crista (2) on this part of the skull; another part lies between the cristae (2) and (5).

Attachment by means of an internal aponeurosis. This occurs in the first place by the caudal part of the aponeurosis (2b); this aponeurosis (2b) extends within the muscle, no doubt as an internal aponeurosis; to the medial surface of aponeurosis (2b) also muscle fibres of the rostro-medial part of the muscle are attached; this caudal part of the aponeurosis (2b) is attached to the crista (2), which separates the lateral surface from the ventral surface of the processus postorbitalis and shows a curved course; the rostral part (2a) of this aponeurosis (2) is attached to the rostral border of the processus postorbitalis; this part has the shape of a fan; caudalwards aponeurosis (2a) is united to aponeurosis (2b).

In the second place an internal aponeurosis occurs with the thin aponeurosis (3) which caudalwards joins the aponeurosis (2b); this aponeurosis (3) is attached to the ventral border of the fossa temporalis and to the tuber (11) on the processus oticus quadrati.

Attachment by means of an external aponeurosis. This occurs in the first place by the external aponeurosis (1) which covers the caudo-lateral part of the muscle, being no doubt a surface aponeurosis; this aponeurosis is attached to the crista (1); the caudal part of this crista (1) limits the fossa temporalis above and behind and extends rostralwards on the lateral surface of the processus postorbitalis as far as the rostral border of the processus.

A second attachment by means of an external aponeurosis takes place by the aponeurosis (5) which is attached to crista (5) which rostralwards separates the ventral surface and the medial surface of the processus postorbitalis and which caudalwards extends as far as the caudal end of crista (2).

1b. Musculous attachment. This occurs to the lateral surface of the lower jaw. This surface has the shape of a quadrangle which extends from the dorsal border as far as about 1 mm above the ventral border.

Attachment by means of an internal aponeurosis. This occurs in the first place by the strong aponeurosis (4) which is attached to the top of the processus coronoideus; this aponeurosis (4) shows two parts; the larger part shows a penniform structure, its shaft or quill being composed of a rather thick cord of connective tissue elements; the smaller part is a much smaller blade, attached to the medial surface of the first part along the thick cord mentioned above.

In the second place an internal aponeurosis occurs with the aponeurosis (8) which lies on the caudal side of a bony tuberosity on the dorsal border of the lower jaw, on the lateral side of aponeurosis (9).

Attachment by means of an external aponeurosis. This occurs in the first place by the aponeurosis (6), which is attached to the small crista (6) on the lower jaw.

In the second place it occurs with the aponeurosis (7), which lies on the rostral side of a bony tuberosity on the dorsal border of the lower jaw and which covers the medial side of the muscle, no doubt as a surface aponeurosis.

In the third place the attachment by means of an external aponeurosis occurs by the aponeurosis (9) which lies on the caudal side of the bony tuberosity on the dorsal border of the lower jaw, on the medial side of aponeurosis (8), no doubt also as a surface aponeurosis.

2a. Surface of the area of attachment. The area in the fossa temporalis is no doubt concave as well as the area between crista (2) and (5). The tuber (11) on the processus oticus quadrati has the shape of a tuber. The cristae (1), (2) and (5) are distinctly crista-like.

2b. Surface of the area of attachment. This area for musculous attachment shows a convex vault extending from the base of the processus coronoideus rostralwards as far as the caudal border of the foramen pro ramo mandibulare externo nervi trigemini. This vault lies between two concave declivities, one on its dorsal and one on its ventral side. The processus coronoideus has the shape of a blunt, short process according to the figures. The crista (6) is distinctly crista-like. The tuberosity on the dorsal border of the lower jaw has no doubt the shape of a tuber.

3. Mutual course of the muscle fibres. This course in the muscle as a whole is for the larger part dependent on the fact, that the aponeuroses all run in a more or less parasagittal plane.

The muscle fibres of the caudo-lateral part of the muscle attached to the medial surface of aponeurosis (1) run to the lateral surface of aponeurosis (4a), those which are attached to the lateral surface of aponeurosis (2b) run to the sharp angle formed by aponeuroses (4a) and (4b), those which are attached to both sides of aponeurosis (3) run to the obtuse angle, formed by aponeurosis (4a) and (4b). The muscle fibres which are musculously attached to the osseous surface of the skull, lying in between crista (1) and crista (2), are divided as well to the same three categories. The muscle fibres attached to the medial surface of the external aponeurosis (1) converge rostro-ventralwards.

The muscle fibres of the rostro-medial part of the muscle attached to aponeurosis (5) which extends between aponeurosis (8) and (9) probably run to these aponeuroses (8) and (9). The aponeurosis (8) lies on the medial side of the aponeurosis (2b). Part of the muscle fibres of this rostro-medial part of the muscle are attached to this aponeurosis (2b). The aponeurosis (9) is an external aponeurosis on the medial side of the muscle. The same is the case with aponeurosis (7), which lies on the medial side of aponeurosis (2a). Part of the muscle fibres are attached in a musculous way to the lower jaw.

(H XXVIII) iii. *Phasianus colchicus* L. (Galli; Aves)

a. Musculus adductor mandibulae externus

(Burggraaf, 1954, pp. 293-303; personal communication)

This strongly developed muscle runs a) from the lateral surface of the lower jaw in a medio-caudo-dorsal direction, laterally, ventrally and caudally of the orbita, b) to the lateral, ventro-lateral and rostro-ventral surface of the cerebral skull.

1a. Musculous attachment. This occurs with the minority of the muscle fibres to a part of the lateral surface of the lower jaw. This area is bordered by the dorsal edge of the lower jaw, by two cristae (7), (9), by one groove (su.); it does not show special surface structures.

Attachment by means of an internal aponeurosis. Attachment in an aponeurotic way of the majority of the muscle fibres occurs to five aponeuroses, which can be taken as components of one compound aponeurosis but which can also be divided into three parts between which the connection is rather loose. The first part is composite (it consists of aponeurosis (1) and (3)), the second part is also composite (it consists of aponeurosis (5) and (7)), the third part is constituted by only one aponeurosis (9). These aponeuroses can also be divided into internal aponeuroses (aponeurosis (3) and (5); personal communication) and external surface aponeuroses (aponeurosis (1), (7) and (9); personal communication).

Aponeurosis (3) is an internal aponeurosis (personal communication); it bears muscle fibres on the ventral and on the dorsal side of the medial surface but also on the lateral surface of this aponeurosis. This aponeurosis (3) is thickened at its base and has the character of a tendon. The aponeurosis (3) is much longer and narrower than aponeurosis (1).

Aponeurosis (5) is also an internal aponeurosis (personal communication); it bears muscle fibres on its rostral and on its caudal surface. This very large and strong aponeurosis (5) is a curved plane, showing a latero-ventral and a medio-dorsal wing. The aponeurosis (5) is connected with aponeurosis (7) over the full length of its medial edge along a caudally inclined line.

Attachment by means of an external aponeurosis. Aponeurosis (1) is an external aponeurosis with only one wall present (personal communication). It is a surface aponeurosis which does not show muscle fibres attached to the caudal surface. This aponeurosis (1) which constitutes the rather short and broad medial part of the muscle is with its lateral edge connected with the caudal edge of aponeurosis (3) along half of its length.

Aponeurosis (7) is an external aponeurosis with only one wall present (personal communication). It is a surface aponeurosis which does not show muscle fibres attached to the medial surface (according to Fuchs, 1954, p. 458 some muscle fibres may sometimes be attached to the medial surface). This aponeurosis (7) is also large, but it is less strongly developed than aponeurosis (5). The aponeurosis (7) shows a slightly curved plane; the caudal margin is slightly curved in a lateral direction. The rostral margin of aponeurosis (7) like its caudal margin is very thin and connected with the caudal edges of aponeuroses (1) and (3) along a line parallel to the line connecting aponeurosis (5) with aponeurosis (7). However, the aponeuroses (7) and (1-3) are connected over a short distance only.

Aponeurosis (9) is an external aponeurosis representing a very wide gutter; the rostral firm part is short, the caudal thinner part is longer; these parts represent a short upside-down gutter (personal communication). The short external aponeurosis (9) is strongly developed and connected with the lateral edge of aponeurosis (5); caudally it is thin; the caudal edge is connected with the caudal edge of aponeurosis (7).

1b. Musculous attachment. This occurs with the minority of the muscle fibres to two areas on the cerebral skull. — The first area lies on the rostro-ventral surface of the cerebral skull, so on the caudal wall of the orbita; it is bordered dorsally by the slightly developed crista (2). — The second area lies on the lateral and ventro-lateral surface of the cerebral skull in the fenestra postorbitalis and dorsally of it. This second area is bordered dorsally by two cristae (the most rostrally situated crista (8a) and the caudal crista (8b) running in a sometimes slightly S-shaped curve). — Moreover there is a musculous attachment to the caudal surface of the processus postorbitalis and to the medial surface of the processus temporalis. On the ventral side of the crista (10) lies another part of this area of musculous attachment. The crista (10) lies at the ventral edge of the processus temporalis and in a rostral direction constitutes the dorsal edge of the bony continuation of the processus temporalis and ends on the tip of the processus postorbitalis (this bony continuation of the processus temporalis shows a number of cristae on the various edges). A few muscle fibres are attached to the processus articularis quadrati close to the strongly developed spina (6).

Attachment by means of an internal aponeurosis. Attachment in an aponeurotic way of the majority of the muscle fibres occurs to five aponeuroses which are connected with each other at a few places, but which can also be divided into five aponeuroses, one (nr. (4)) of which is composed of four parts (they are partly internal aponeuroses, partly external aponeuroses), the other four aponeuroses being simple aponeuroses; one of these is an internal (6), the three remaining are simple surface aponeuroses ((2), (8), (10)), which means external aponeuroses with only one wall (personal communication).

Attachment by means of an internal aponeurosis occurs in the case of some parts of the very complex aponeurosis (4), which we can consider as a branched or ramified aponeurosis. Internal aponeuroses are the ossified aponeurosis (4a), which is a bony continuation of the processus temporalis, and a small thin internal aponeurosis (4b) attached to the medio-caudal edge of the ossified part of aponeurosis (4a). To both surfaces of the ossified aponeurosis (4a) muscle fibres are attached, except to a part of its medial surface; so this internal aponeurosis (4a) is partly a surface aponeurosis. To both surfaces of the internal aponeurosis (4b) muscle fibres are attached.

Attachment by means of a simple aponeurosis which is an internal one (personal communication) takes place in the case of aponeurosis (6); to this aponeurosis muscle fibres are attached to both surfaces, to its medial border, its rostral and its caudal surface and to its tip. This very strong and long aponeurosis shows a thickened medial border which has the character of a tendon especially at the attachment; laterally this aponeurosis is rather thin; this aponeurosis (6) is attached to spina (6) on the processus articularis quadrati.

Attachment by means of an external aponeurosis. This occurs in the case of two other aponeuroses (4c), (4d), attached to the surface of the bony part (4a) and in the case of the simple surface aponeuroses (2), (8), (10) mentioned above. The external aponeurosis (4c) is a very wide gutter which at the same time is very short and broad; it lies upside-down (personal communication). The external aponeurosis (4d) lacks one of the walls (personal communication).

The strong external aponeurosis (4c) is attached to the rostral edge of the ossified part (4a); muscle fibres are attached to the lateral surface, not to the medial surface of this surface aponeurosis; the rostral part of the aponeurosis is curved laterally.

The external aponeurosis (4d) with one wall only (personal communication) is attached to the medial surface of aponeurosis (4c) and to the ventral edge of the ossified aponeurosis (4a); the muscle fibres are attached to the ventral surface of this surface aponeurosis (4d).

Attachment by means of a simple external aponeurosis takes place in the case of the surface aponeurosis (2); only one wall is developed (personal communication); no muscle fibres are attached to the latero-dorso-rostralwards facing surface; the lateral part of this aponeurosis is more strongly developed than the medial part; this aponeurosis (2) is attached to crista (2).

Attachment by means of a solid simple surface aponeurosis takes place in the case of aponeurosis (8), which lies on the lateral surface of the muscular tissue; to the medial surface of this aponeurosis muscle fibres are attached. The aponeurosis is attached to crista (8a) and crista (8b).

Attachment by means of a simple surface aponeurosis takes place in the case of aponeurosis (10), which lies on the lateral surface of the muscular tissue. The lateral edge of aponeurosis (4c) and the lateral edge of aponeurosis (6) are connected with this aponeurosis (10); ventrally aponeurosis (10) is indirectly (by means of fascia) continuous with surface aponeurosis (9) which is attached to the lower jaw. The aponeurosis (10) is attached to crista (10).

2a. Surface of the area of attachment. Part of the area of musculous attachment is the fossa lateralis on the lateral surface of the lower jaw, which has the shape of a fossa.

The aponeurosis (1) and the thickened base of aponeurosis (3) which base has the character of a tendon, are connected to each other and are attached to the strongly developed spina (1, 3) on the dorsal edge of the lower jaw.

The curved plane of aponeurosis (5) and that of aponeurosis (7) are attached to the strongly developed crista (5), to the less developed crista (7) and to the strongly developed spina (5, 7) which is formed by the junction of the two cristae, all lying on the lateral surface of the lower jaw. The slightly developed aponeurosis (7) is attached to the slight crista (7) (ventrally of spina (5, 7)) or to the almost smooth parts of the bony surface (crista (7) between spina (1, 3) and spina (5, 7)). The aponeurosis (7) reaches as far as the strongly developed spina (1, 3), directed dorsalwards and situated on the dorsal edge of the lower jaw.

The aponeurosis (9) is attached to the lateral surface of the lower jaw ventrally of the groove (su.) and to crista (9), which is curved.

2b. Surface of the area of attachment. The area of musculous attachment on the surface of the cerebral skull does not show special surface structures.

The crista (2) of aponeurosis (2) lies on the rostro-ventral surface of the cerebral skull; the aponeurosis (2) as well as the crista (2) is slightly developed; its lateral part is more strongly developed than the medial part.

No details are mentioned about the development, the size *etc.* of the cristae (4b), (4c), (4d), (8a), (8b) and (10). As we have already mentioned, the internal aponeurosis (4a) is ossified; it is a bony continuation of the processus temporalis.

Spina (6) is strongly developed; it is directed dorso-rostrally.

3. Mutual course of the muscle fibres. The muscle fibres which are attached to the dorsal edge of the lower jaw (starting at crista (9) as far as spina (1, 3)), no doubt in a musculous way, to the surface of the external aponeurosis (1), and to the ventral part of the medial surface of the internal aponeurosis (3), run to the external aponeurosis (2) and to the surface of the cerebral skull (ventrally of crista (2)) (showing a musculous attachment), in a caudo-dorsal direction; the mutual course of the muscle fibres is not indicated, perhaps they run more or less parallel.

The muscle fibres which are attached to the dorsal part of the medial surface of the internal aponeurosis (3) run to the caudal surface of the processus postorbitalis, to the lateral surface of the cerebral skull, both showing a musculous attachment, and to the medial surface of the external aponeurosis (8), in caudo-dorsal directions; these muscle fibres run divergently.

The muscle fibres which are attached to the lateral surface of the internal aponeurosis (3) run to the caudo-dorsal part of the medial surface of the internal aponeurosis (4a), to the medio-rostral surface of the internal aponeurosis (4b), to the medial surface of the processus temporalis (showing a musculous attachment) and to the medial surface of the external aponeurosis (8), in dorso-caudal and latero-dorso-caudal directions; the mutual course of the muscle fibres is not indicated; perhaps they run divergently.

The muscle fibres which are attached to the lateral surface of the lower jaw (between the spinae (1), (3) and (5, 7)), no doubt in a musculous way, and to the lateral surface of the part of the external aponeurosis (7), situated between aponeurosis (5) and aponeurosis (3), run to the ventral edge of the internal aponeurosis (4a), in a caudo-dorsal direction; the mutual course of the muscle fibres is not indicated, perhaps they run more or less parallel.

Of the muscle fibres which are attached to the fossa lateralis on the lateral surface of the lower jaw, in a musculous way, to the rostral part of the external aponeurosis (9) and to the rostral surface of the internal aponeurosis (5) the most rostro-medially situated muscle fibres run to the external aponeuroses (4c) and (4d) and to the tip of the internal aponeurosis (4a), in a caudo-dorsal direction and of these muscle fibres the more caudo-laterally situated muscle fibres run to the caudal surface of the internal aponeurosis (4b), to the lateral surface of the internal aponeurosis (4a), to the caudal part of the ventral surface of the external aponeurosis (4d), to the ventro-lateral surface of the cerebral skull (a very small place of attachment, ventro-medially close to the base of the processus temporalis) and to the medial surface of the surface aponeurosis (10), also in a caudo-dorsal direction.

The muscle fibres which are attached to the tip of the internal aponeurosis (5) run to the lateral surface of the internal aponeurosis (4a), to the medial surface of the surface aponeurosis (10), to the ventro-lateral surface of the cerebral skull (showing a musculous attachment) and to the rostral surface of the internal aponeurosis (6); the muscle fibres diverge like a fan.

The muscle fibres attached to the lateral surface of the lower jaw (area bordered by crista (5), crista (7) and the rostral part of the groove (su.)) (attached no doubt in a musculous way) and those attached to the caudal part of the external aponeurosis (9) run to the tip of the internal aponeurosis (6); the muscle fibres converge.

The muscle fibres which are attached to the caudal surface of the internal aponeurosis (5) run to the rostral surface and the medial border of the internal aponeurosis (6); the muscle fibres run in directions varying from medio-caudal to latero-caudal.

The muscle fibres which are attached to the lateral surface of the external aponeurosis (7) run to the caudal surface and the medial border of the internal aponeurosis (6), to a very small area on the surface of the processus articularis quadrati, where it shows a musculous attachment close to spina (6), and to the ventro-lateral surface of the cerebral skull, also showing a musculous attachment; the muscle fibres converge in directions from dorsal to latero-dorsal.

The area of musculous attachment on the lower jaw is larger than on the cerebral skull.

The course of the muscle fibres in general is also determined by the fact that the aponeuroses in this muscle are alternately placed and that this muscle is a "compact" one, which means that the two ends do not consist of divergent branches (Burggraaf & Fuchs, 1955, p. 98).

b. Musculus adductor mandibulae internus pterygoideus

(Fuchs, 1954, pp. 462-470; Burggraaf & Fuchs, 1955, pp. 98, 99; personal communication)

This very strongly developed muscle runs a) from the medial and the lateral surface of the lower jaw and from the ventral, partly also from the dorsal surface of the processus angularis internus, b) towards the following five elements: towards the rostro-medial part of the pterygoid, the wall of the tubae auditivae, the processus basipterygoideus, the palatinum and the connective tissue in the roof of the mouth cavity. — This muscle runs in a rostro-dorso-medial direction (dorsal branch), in a medio-rostral direction (lateral branch) and in a slightly medio-rostral direction (medial branch). — This muscle is one single muscle though its structure is rather complicated, since it is "ramified", showing three "branches" already mentioned above (a dorsal branch; a ventral branch in its turn can be divided into a lateral branch and a medial branch; the lateral and the medial branch are clearly distinguishable only at their rostral end, but for the rest they are closely connected as parts of an undivided muscle). — The dorsal branch is the least developed of the three parts; the lateral and the medial branch are very strongly developed.

1a. Musculous attachment. This occurs with the dorsal branch of the muscle on the medial surface of the lower jaw to an area which is situated just rostrally of the processus angularis internus. This area of attachment is bordered rostro-dorsally by crista (15) and crista (17); the latter forms the very slightly developed spina (15a). The dorsal and ventral surface of the processus angularis internus also bears a limited number of muscle fibres.

Attachment in a musculous way occurs in the second place with the lateral branch of the muscle on the medial surface, the ventral edge and a small part of the lateral side of the lower jaw and the processus angularis internus. The area of attachment on the medial surface of the lower jaw is situated rostrally of the processus angularis internus. This area is bordered dorsally by the ventral border of the area of attachment of the muscle fibres of the pars dorsalis and — more rostrally — by crista (17). In the immediate vicinity of crista (17) a number of muscle fibres are attached "dorsally" of the pars dorsalis. Moreover this area of attachment extends on the ventral surface of the processus angularis internus on either side of costa β (this costa runs on the surface of the cone-shaped processus along a longitudinal radius). A small extension of the area of attachment lies on the lateral surface in the fossa processus mandibularis externi, caudo-ventrally of the processus mandibularis externus.

Attachment in a musculous way occurs in the third place with the medial branch of the muscle to the medial part of the processus angularis internus. This area of attachment is situated on the ventral surface on either side of costa β and on the dorsal surface rostrally of the arciform ridge δ.

Attachment by means of an internal aponeurosis. This occurs with aponeurosis (19) of the medial branch of the muscle. This aponeurosis (19) has to be considered as an internal aponeurosis (personal communication). For the greater part, however, it is a dorsal surface aponeurosis, but to the dorsal surface of this aponeurosis a few muscle fibres of a separate bundle of the pars medialis or medial branch of the muscle are attached. This aponeurosis (19) is strongly developed; its length is 9 mm; it is tangentially attached against the ventral surface of the rounded end of the processus angularis internus; the small place of attachment is caudally bordered by the crista (19). The surface of the aponeurosis (19) is vaulted along its longitudinal axis; to its concave, ventral surface the majority of the muscle fibres are attached.

Attachment by means of an external aponeurosis. This occurs with the external aponeurosis (15) of which only one wall is developed (personal communication). It is a surface aponeurosis of the dorsal branch of the muscle. This aponeurosis (15) is attached to spina (15a), crista (15) and spina (15b), all lying on the lower jaw; this dorsal surface aponeurosis is slightly developed; it is about triangular; its length amounts to 6.5 mm.

Attachment by means of an external aponeurosis, showing but one developed wall (personal communication), also occurs by the dorsal surface aponeurosis (17) of the lateral branch of the muscle; this aponeurosis is narrow, but strongly developed; its length is about 8.5 mm; it is attached to crista (17) on the lower jaw.

1b. Musculous attachment. This occurs with the dorsal branch of the muscle on the rostro-medial part of the pterygoid, near the basipterygoid articulation on the dorsal surface only and more caudo-laterally also on the ventral surface.

Attachment in a musculous way occurs in the second place with the lateral branch of the muscle on the lateral or dorso-lateral, sometimes latero-dorsal border of the palatinum. This place of attachment is very narrow and lies between crista (18a) and crista γ and rostrally of crista (18b) (this crista (18b) is clearly visible especially when crista γ is practically absent).

Attachment in a musculous way occurs in the third place with the medial branch of the muscle to the palatinum (the area lies between crista (20) and crista γ and caudally of crista (18b)); a very small place of attachment is situated near the basipterygoid articulation, on the processus basipterygoideus and on the ventral surface of the pterygoid. Moreover there is an area of attachment on the wall of the fused tubae auditivae. At the lateral side of the muscle a muscle bundle is divided off and runs to the connective tissue in the roof of the mouth cavity.

Attachment by means of an internal aponeurosis. This occurs with the aponeurosis (16) which is partly an internal aponeurosis, partly a surface aponeurosis, of the dorsal branch of the muscle (personal communication). This aponeurosis (16) is rather strongly developed; at the most rostro-medial end of the pterygoid aponeurosis (16) is a ventral surface aponeurosis, on the caudo-lateral part of the pterygoid it is an internal aponeurosis; the length of the aponeurosis varies up to 8.5 mm.

Attachment by means of an external aponeurosis. This occurs with the surface aponeurosis (18) of the lateral branch of the muscle; only one wall of this external aponeurosis is developed (personal communication). This aponeurotic attachment is more important than the musculous attachment to the palatinum. This aponeurosis (18) is the very strongly developed ventral surface aponeurosis (18); its length amounts to 15 mm; for the greater part it is attached to crista (18a). The rostro-medial margin of this aponeurosis (18) is curved dorsalwards; this curved part is attached to crista (18b).

An attachment by means of an external aponeurosis also occurs with the surface aponeurosis (20) of the medial branch of the muscle, only one wall of this aponeurosis being developed (personal communication). It is a very strongly developed "branched" ventral surface aponeurosis. The medial part, aponeurosis (20a), is attached to crista (20); its greatest length amounts to about 12 mm. The lateral part is attached to the connective tissue in the roof of the mouth cavity, rostrally this part has the character of a tendon; the length of this lateral part of the aponeurosis is equal to that of the medial part. The medial and the lateral part of this aponeurosis (20) are connected with each other caudally.

2a. Surface of the area of attachment. The area of musculous attachment of the dorsal branch of the muscle on the medial surface of the lower jaw just in front of the processus angularis internus is, according to the figures, curved and hollow. The spina (15a) has the shape of a spina.

The area of musculous attachment of the lateral branch of the muscle on the medio-dorsal surface of the lower jaw just in front of the processus angularis internus shows a curved and hollow area, as well as a separating ridge, as a part of a fossa, according to the figures.

The area of musculous attachment of the medial branch of the muscle on the processus angularis internus is part of the surface of a cone-shaped processus.

The cristae (15), (17) and (19) have the shape of a crista, the spinae (15a) and (15b) have the shape of a spina. The arciform ridge δ has the character of a costa in a number of cases, in others that of a crista. The costa β has the shape of a costa. The processus angularis internus is cone-shaped.

2b. Surface of the area of attachment. This area of musculous attachment of the dorsal branch of the muscle on the pterygoid is a rounded surface. Especially the rostro-medial part of the latero-rostral border of this pterygoid is shaped like a crista (16), being used for attachment of the dorsal branch.

The area of musculous attachment of the lateral branch and of the medial branch of the muscle on the very narrow border of the palatinum is perhaps long, rectilinear and somewhat rounded.

The cristae (16), (18a), (18b) and (20) have the shape of a crista.

3. Mutual course of the muscle fibres. These fibres of the caudal part of the pars dorsalis of the muscle are sometimes curved fairly considerably caudalwards.

The pars lateralis of the muscle curves round the ventral edge of the lower jaw.

The density with which the muscle fibres of the lateral branch are implanted on the lower jaw is very divergent: the attachment to the caudal part of the medial surface is rather close; rostralwards the density of the muscle fibres gradually diminishes; on the processus angularis internus the muscle fibres stand close together. In the fossa processus mandibularis externi the density decreases considerably from the caudal border rostralwards. At the most rostral end and near the ventral edge the muscle fibres are connected with the bone by loose connective tissue only.

(H XXVIII) iv. *Ardea cinerea* (L.) (Gressores; Aves)

a. Musculus adductor mandibulae internus pterygoideus

(Bas, 1955, pp. 103-108; personal communication)

This muscle runs a) from the ventral and dorsal surfaces of the palatinum and from the medial and lateral surfaces of the pterygoid, b) to the medial surface and to a small area on the lateral surface at the caudal end of the lower jaw. This muscle is very strongly developed. The left and right palatinum lie side by side in the roof of the mouth cavity; they are fused in the median at their rostral and caudal ends, but their middle parts surround a medial foramen.

1a. Musculous attachment. This takes place to the ventral surface of the palatinum, occupying practically this entire surface according to the figure.

Attachment in a musculous way is found in the second place to the dorsal surface of the palatinum; this place of attachment is situated on the lateral wing, which is thin, and bent rather far ventralwards; it ends suddenly at the caudal end of the palatinum; along its free end this wing bears crista (18). This dorsal place of attachment, situated on the lateral wing, faces latero-dorsalwards. The rostral part of this place of attachment is also extended on a wing projecting from the dorsal surface of the palatinum in a latero-dorsal direction; this wing surrounds the medial foramen.

In the third place we find a musculous attachment of a part of the pars palatinalis of the muscle to a small area of the lateral surface of the pterygoid, according to the figure.

In the fourth place there is a musculous attachment of a part of the pars pterygoidea lateralis of the muscle to the lateral surface of the pterygoid (according to the figure the larger part of this surface).

In the fifth place there is a musculous attachment of a part of the pars pterygoidea medialis of the muscle to the medial surface of the pterygoid (according to the figure the larger part of this entire surface); this surface is flattened in a medio-lateral direction; the ventral side is narrow, but still it is clearly somewhat flattened, especially in the rostral part.

Attachment by means of an internal aponeurosis. This is found with aponeurosis (18) which shows (i) a vertical internal part lying in between the muscle fibres coming from the aponeurosis (15) on one side and from aponeurosis (13) and from the inner side of the lower jaw on the other side and (ii) an external part which represents a ventrally situated lateral surface aponeurosis, the pars palatinalis of the muscle (personal communication). The aponeurosis has a medial part which bends in a vertical direction; this aponeurosis (18) is attached to the abrupt caudal rim of the lateral wing of the palatinum, constituting crista (18).

A second internal aponeurosis is found in aponeurosis (20). This aponeurosis lies as an internal aponeurosis receiving on its dorsal surface muscle fibres from the pars pterygoidea medialis of the muscle and on its ventral surface muscle fibres from the pars palatinalis of the muscle (personal communication). The aponeurosis (20) is attached to crista (20).

Attachment by means of an external aponeurosis. This occurs with the aponeurosis (16) which is no doubt a surface aponeurosis of the pars palatinalis of the muscle. This aponeurosis (16) is either a double-walled external aponeurosis covering the ventral and the medial side of the muscle, both walls being at right angles to each other, or it only shows the medial wall (personal communication). This aponeurosis is attached to crista (16) on the free edge of the medial wall of the inversed V-shaped groove in the ventral surface of the palatinum; the caudal part of this groove is ventrally roofed over by aponeurosis (16); this aponeurosis extends in a latero-caudal direction on the ventral surface of the muscle; the aponeurosis makes a bend and comprises a vertical part which covers the medial surface of the muscle, owing to the fact that the crista (16) bends in a medio-dorsalward direction at the caudal end of the palatinum.

Another external aponeurosis which shows one wall only is the slightly developed surface aponeurosis (22) (personal communication) to which the pars pterygoidea lateralis of the muscle is attached. This aponeurosis (22) is attached to the pterygoid, showing crista (22).

1b. Musculous attachment. This occurs to the medial surface of the lower jaw. This area of attachment is bordered rostro-dorsally by the medio-rostral border of the caudal cavitas glenoidalis; its caudal and dorso-caudal border coincides with the caudal edge of the lower jaw; its ventral border coincides with the ventral edge of the lower jaw; its rostral border is the crista (13).

A second area of musculous attachment is a small place which lies separately on the medial surface of the lower jaw; this place lies rostrally or rostro-ventrally of the medio-rostral border of the caudal glenoid cavity; ventro-rostrally it borders on the area of attachment of the musculus adductor mandibulae internus pseudotemporalis profundus; dorsally it borders on crista (19) which is situated on the medial edge of the dorsal surface of the lower jaw.

A third area of musculous attachment is a small triangular area on the lateral surface of the lower jaw; to this lateral surface the most lateral muscular fibres of the muscle are attached, passing over the ventral edge of the lower jaw which is not sharp.

Attachment by means of an internal aponeurosis. This is found with the aponeurosis (15) of the pars palatinalis of the muscle. The caudal part of this aponeurosis is a distinct internal aponeurosis (personal communication). This caudal part is band-shaped; it is narrow, vertical and a little bent. The aponeurosis probably narrows gradually in the rostral direction (personal communication). To its medial surface muscle fibres are attached, running to two parts of aponeurosis (16), to its lateral surface muscle fibres are attached running to aponeurosis (18), to the pterygoid and to aponeurosis (20). From the rostral part of this aponeurosis (15) muscle fibres run in a lateral, dorsal and median direction to the gutter formed by the palatinum (personal communication). The aponeurosis (15) is attached very far caudalwards to the lower jaw by means of crista (15).

Attachment by means of an external aponeurosis. This occurs with the attachment of the pars palatinalis of the muscle by means of the aponeurosis (13) to the lower jaw; this aponeurosis is no doubt an external aponeurosis as it covers the muscle on its lateral surface; it is attached to crista (13).

A second attachment by means of an external aponeurosis occurs with the aponeurosis (17) of the pars pterygoidea medialis of the muscle. This aponeurosis (17) is an external aponeurosis, showing only one wall, lying on the medio-dorsal surface of the pars pterygoidea medialis of the muscle (personal communication). The aponeurosis (17) is attached to crista (17).

A third attachment by means of an external aponeurosis is found in the case of aponeurosis (19) which is an external aponeurosis showing one wall only (personal communication). It covers as a dorsal surface aponeurosis the pars pterygoidea lateralis of the muscle. The aponeurosis is attached to crista (19).

2a. Surface of the area of attachment. The ventral surface of the palatinum is flat in its rostral part. — The dorsal place of attachment to the palatinum is nearly flat.

The medial surface of the pterygoid is slightly concave, the lateral surface is slightly convex.

The crista (16) is found on the free edge of the ventrally directed wing which is found more caudally on the medial border of the palatinum and on the lateral border of the medial foramen; the crista (16) follows the free edge of this wing, and is bent at the place where the free edge suddenly ends at the caudal end of the palatinum in a dorsal direction.

The crista (18), found on a similar free edge on the lateral border of the palatinum, follows this free edge; it is bent at the place where the free edge suddenly ends at the caudal end of the palatinum in a medio-dorsal direction.

The crista (20) is sharp; it is found on the border between the medial and the ventral surface of the pterygoid.

The crista (22) is very slight; it is the border between the lateral and the ventral side of the pterygoid; its rostral part, however, shifts somewhat so that it is situated on the lateral surface.

2b. Surface of the area of attachment. The entire place of attachment on the medial surface of the lower jaw is practically flat. The caudal end of the lower jaw is somewhat curved medially; thus the surface to which the muscle is attached faces rostro-ventro-medialwards.

The small triangular area of musculous attachment on the lateral surface of the lower jaw is a very shallow fossa.

The crista (13) runs from the medio-rostral border of the caudal cavitas glenoidalis in a rostro-ventral direction to the ventral edge of the lower jaw.

The crista (15) runs on the medial surface of the lower jaw closely along and parallel to the caudal edge of the lower jaw.

The crista (17), which is hardly discernible, lies on the dorsal part of the narrow strip between crista (15) and the caudal edge of the lower jaw.

The crista (19) is small, but sharp; it lies on the dorsal side of the lower jaw.

3. Mutual course of the muscle fibres. The muscle fibres attached to the rostral part of the no doubt external aponeurosis (13) on the lower jaw run to the latero-dorsal places of attachment on the palatinum and to the wing which surrounds the fenestra medio-palatinalis and quite rostrally to the membranaceous roof of the mouth cavity between palatinum and jugale.

Muscle fibres attached to the caudal part of the external aponeurosis (13) on the lower jaw run to the internal aponeurosis (18).

Muscle fibres attached to the rostral part of the internal aponeurosis (15) on the lower jaw, run to the walls of the inversed V-shaped groove in the ventral surface of the palatinum, and to the aponeurotic roof formed by the external aponeurosis (16).

Muscle fibres attached to the caudal part of the internal aponeurosis (15) on the lower jaw, run in medial and ventral directions to the external aponeurosis (16), in lateral directions to the vertical part of the internal aponeurosis (18) (this vertical part of aponeurosis (18) lies between muscle fibres attached to aponeuroses (15) and (13)), in dorsal directions to a small area on the rostral part of the narrow ventral surface on the pterygoid, and to the ventral surface of the internal aponeurosis (20).

The no doubt external aponeurosis (13) and the internal aponeurosis (15) (both attached to the lower jaw) and the medial surface aponeurosis (16) and the internal aponeurosis with the external lateral surface aponeurosis (18) (both attached to the palatinum) are alternating aponeuroses; muscle fibres run between these aponeuroses, but they also are connected to the bony parts.

The muscle fibres attached directly to the lower jaw between the cristae (13) and (15) and those attached in a narrow range between crista (15) and the caudal edge of the lower jaw, are attached at their other end to the caudal end of aponeuroses (16) and (18).

Muscle fibres of the pars pterygoidea lateralis attached to the pterygoid, musculously as well as by means of the external aponeurosis (22), run in a caudo-lateral direction to the small separate place of musculous attachment on the medial surface of the lower jaw and to the external aponeurosis (19).

Muscle fibres of the pars pterygoidea medialis attached musculously to the medial surface of the pterygoid as well as to the internal aponeurosis (20), run in a caudal direction to the external aponeurosis (17) as well as (as a thin layer of muscle fibres) to the narrow strip of the bony surface between the cristae (17) and (15).

(H XXVIII) v. *Podiceps cristatus* L. (Podicipedes; Aves)

a. Musculus adductor mandibulae internus pterygoideus

(Bams, 1956, pp. 257-262; personal communication)

This very strongly developed muscle runs a) from the palatinum and from the pterygoid, b) to the caudo-ventro-medial side of the lower jaw. It entirely occupies the space between palatinum, pterygoid, quadratum and lower jaw at the ventral side of the skull. Rostro-dorsally it lies against the eye-ball and the caudo-dorsal surface abuts on the musculus protractor quadrati et pterygoidei. The muscle can be divided into a greater pars lateralis and a smaller pars dorsalis. At its attachment on the lower jaw the pars lateralis is single, but towards its attachment on the palatinum it divides into two branches, *viz.* 1. a dorso-lateral branch, which is attached on the dorsal surface of the palatinum and in the dorsal side of the internal aponeurosis (XXII); 2. a ventro-medial branch, which is attached to the ventral surface of the palatinum and in the dorsal surface of the superficially situated external aponeurosis (XX), and also to the ventro-medial surface of the pterygoid. This division into two branches is not sharp. The pars dorsalis is an independent third part of this muscle; it is attached on the pterygoid, partly musculously, partly by means of aponeurosis (XXVII) (for XVII on p. 257, 10th line from bottom, read XXVII; personal communication). — The course of the muscle fibres allows a division of the muscle into five parts, as we will see.

1a. M u s c u l o u s a t t a c h m e n t. This occurs to the dorsal surface of the palatinum; its size and shape is not described; here the dorso-lateral branch is partly attached.

A second area of musculous attachment is found on the ventral surface of the palatinum; this occupies the entire area laterally of the edge (I); here the ventro-medial branch is partly attached.

A third area of musculous attachment occurs on the pterygoid, *viz.* on the entire flat dorsal surface and the ventral surface, except the smooth ledges; these surfaces are entirely occupied by musculous attachments. The medio-caudal part of the ventral surface receives the muscle fibres, lying at the side of the knob of the basisphenoid. To the ventro-medial surface of the pterygoid the ventro-medial branch of the muscle is partly attached. To the pterygoid the pars dorsalis of the muscle is partly attached.

Attachment by means of an internal aponeurosis. This occurs with the internal very strongly developed aponeurosis (XXII), attached to the marked caudo-lateral edge of the palatinum. This internal aponeurosis (XXII) lies in the dorso-lateral branch of the muscle and is nearly entirely covered by the ventro-medial branch of the muscle. In the dorsal side of this aponeurosis (XXII) the dorso-lateral branch of the muscle is attached. This aponeurosis (XXII) lies practically in the same plane as the caudal flat part of the palatinum.

Attachment by means of an external aponeurosis. The aponeurosis (XX) is an external aponeurosis (personal communication); in the dorsal surface of the superficially situated aponeurosis (XX) the ventro-medial branch of the muscle is partly attached. This aponeurosis (XX) is attached on the ventral surface of the palatinum to the place where the broad caudal part passes into the much narrower rostral part. Over a certain part of this place the aponeurose-fibres insert side by side and also one behind the other at a very acute angle or at an angle of practically zero degrees. The raised edge (c.l.) on the ventral surface of the palatinum is entirely occupied by the attachment of the aponeurosis (XX), which is produced along it caudalwards.

A second external aponeurosis is the aponeurosis (XXVII), which bears muscle fibres on one side only (personal communication). This rather short aponeurosis (XXVII) is attached at one place *viz.* the caudal part of the rostral wing (c.q.) of the sharp edge of the flat wing of the pterygoid, which is extended rostro-caudally in a flat plane.

1b. Musculous attachment. This occurs to the entire triangular area on the ventral surface of the lower jaw. This region is inclined in such a way that it slopes from latero-ventral at an angle of 45° medio-dorsalwards. Its medial border is situated on the same level as the articular surfaces or even somewhat higher, while its lateral border lies along the ventral edge of the lower jaw, so that it is at a considerable distance from these articular surfaces at this place. This triangular region, situated between the lines of attachment of the aponeuroses (XIX), (XXI), (XXIII) and (XXV), extends as far as and even somewhat beyond the ventral edge of the lower jaw, so on the lateral side of it. The rostral border of the area of attachment is the crista (c.i.), which rostralwards decreases in height; the caudal part of aponeurosis (XIX) is attached to it. The area of attachment further comprises the small flat and sunken region (s.r.) between the line of attachment of aponeurosis (XIX), the crista (c.n.) and the area of attachment of the rostral part of the musculus adductor profundus. The lateral and caudal border of the area of attachment is a sharp crista to which no special function in relation to the attachment of muscles can be ascribed. The medial border of the area of attachment is the crista (c.p.), which serves for the attachment of the aponeuroses (XXI), (XXIII) and (XXV).

Attachment by means of an internal aponeurosis. The aponeurosis (XXI) is an internal aponeurosis; to both sides muscle fibres, though in unequal numbers are attached (personal communication). At its place of attachment the aponeurosis is superficial, but it dips further down (personal communication). To its most rostral part muscle fibres are attached. The aponeurosis is not strongly developed; it is attached to the crista (c.p.).

A second internal aponeurosis is the aponeurosis (XXIII) (personal communication); in both its surfaces muscle fibres are attached. The crista (c.p.), a shorter, thickened crista, serves for the attachment of the aponeuroses (XXI), (XXIII) and (XXV).

These three aponeuroses are continuous against and upon each other at their bases, but more rostralwards they diverge as more and more muscle fibres are interposed between them. Aponeurosis (XXI) lies superficially; aponeuroses (XXIII) and (XXV) lie deeper in this order from lateral to medial.

Attachment by means of an external aponeurosis. This is the case with the aponeurosis (XIX), which is an external aponeurosis, showing muscle fibres on its ventral surface only (personal communication).

Attachment by means of the aponeurosis (XXV), which is probably an external aponeurosis (personal communication). It looks as though there are only muscle fibres attaching on the ventral side; any attachment on the other side can never be significant, if at all occurring (personal communication). Aponeurosis (XXV) runs at the deepest level in the belly of the muscle; it is the most strongly developed aponeurosis of the three ((XXI), (XXIII) and (XXV)); it is more or less markedly plicated in a longitudinal direction, in some cases showing one or more transverse wings, formed by contiguous and fused plicae.

The aponeurosis (XXIX) is almost certainly an external aponeurosis (personal communication); this aponeurosis (XXIX) is long, weakly developed and attached on the crista (c.n.).

2a. Surface of the area of attachment. The areas of musculous attachment on the dorsal surface and on the ventral surface of the palatinum seem to be flat.

The areas of musculous attachment on the dorsal surface and on the ventral surface of the pterygoid are flat.

The surface of the area of attachment of the aponeurosis (XXII) on the marked caudo-lateral edge of the palatinum is not described in detail.

The bony surface of the palatinum at the place of attachment of the aponeurosis (XX) is not visibly differentiated.

The edge (c.l.) on the ventral surface of the palatinum which is entirely occupied by the attachment of the aponeurosis (XX) is called a "raised edge". This raised edge (c.l.) is the caudal part of the medial border of the ventral place of attachment, which more rostrally projects entirely freely under the connecting part of the palatinum which is highly curved at this place (convexly curved on its dorsal surface and concavely curved on its ventral surface) (this curved connecting part lies between the plate-like surface for attachment just described and the medial ledge sliding along the rostrum sphenoidale).

The area of attachment of aponeurosis (XXVII) on the caudal part of the rostral wing (c.q.) of the sharp edge of the flat wing of the pterygoid which is extended rostro-caudally in a flat plane, is not described in detail.

2b. Surface of the area of attachment. The surface of the musculous attachment to the triangular area on the ventral surface of the lower jaw is not described in detail.

The lower jaw is a little concavely excavated on its ventral edge. The surface of the bone is entirely flat and smooth.

The region (s.r.) for musculous attachment is small, flat and sunken.

The crista (c.p.), to which the aponeuroses (XXI), (XXIII) and (XXV) are attached, is a shorter, thickened crista.

The crista (c.i.) on the lower jaw, to which the caudal part of aponeurosis (XIX) is attached, rostralwards decreases in height. The most rostral part of this aponeurosis inserts on a part of the surface which is in no way differentiated.

The crista (c.n.), to which aponeurosis (XXIX) is attached, is not described in detail.

3. Mutual course of the muscle fibres. The course in this muscle can be described for five parts of the muscle which we can distinguish:

(i) in the first part, the ventro-medial branch of the muscle, the muscle fibres attached in the dorsal surface of the superficially situated aponeurosis (XX) are mainly attached in the ventral surface of aponeurosis (XXV) and in both surfaces of aponeurosis (XXIII). The most caudal part of the ventral branch is musculously attached to the median part of the area of attachment on the lower jaw. The muscle fibres from the most rostral part of aponeurosis (XXI) are musculously attached to the ventral surface of the palatinum;

(ii) in the second part, the dorso-lateral branch of the muscle which is also strongly developed, the muscle fibres attached in aponeurosis (XXII) run to aponeurosis (XIX). The muscle fibres between these two long aponeuroses which overlap each other for the greater part, have the same direction as those of the ventro-medial branch of the muscle. The rostral part of the muscle is musculously attached to the dorsal surface of the palatinum. The caudal part of the muscle is musculously attached to the lateral part of the area of attachment on the lower jaw; this part of the area of musculous attachment on the lower jaw is not separated from that of the ventro-medial branch;

(iii) in the third part, a not very great number of muscle fibres, lying between the two oppositely directed aponeuroses (XXI) and (XXII), run in opposite directions as the bundles mentioned under (i) and (ii). This constitutes with these two strongly developed bundles a pinnate-shaped muscle of considerable strength;

(iv) in the fourth part, rather numerous muscle fibres inserting in the dorsal surface of aponeurosis (XXIII) and being all attached to the caudo-medial half of the ventral surface of the pterygoid, also run in opposite directions. The direction is the same as that of the two main branches of the muscle mentioned under (i) and (ii). On the medial surface of the muscle belly these muscle fibres are not separated from the muscle fibres belonging to aponeuroses (XX) and (XXIII);

(v) in the fifth part, the independent part of the muscle, attached to the dorsal surface of the pterygoid, the direction of the muscle fibres is quite different. Because of the oblique direction of the pterygoid, the distance to the lower jaw is considerably greater at the rostral end of the pterygoid than at its caudal end, which has its consequences in relation to the position and the development of the aponeuroses. The course of muscle fibres inserted farthest rostralwards on the excavated lateral side of the broadened articular surface of the joint with the rostrum sphenoidale, is directed rather strongly caudalwards and these fibres are attached in the long aponeurosis (XXIX). The muscle fibres situated more caudally on the pterygoid are attached entirely musculously to the lower jaw and on the side of the pterygoid; they are attached partly in the fairly short aponeurosis (XXVII). Their direction is entirely lateralwards.

(H XXVIII) vi. *Ondatra zibethica* (L.) (Rodentia; Mammalia)

a. Musculus temporalis

(Van Vendeloo, 1953, pp. 265-268; personal communication)

This muscle runs a) from the roof of the cerebral skull, b) to the lower jaw. The most dorsal part of the muscle covers a great part of the roof of the cerebral skull. The muscle has a characteristic curved form: the muscle fibres run rostralwards, there bend ventralwards and run caudally of the eye to the lower jaw.

1a. M u s c u l o u s a t t a c h m e n t. This takes place to the roof of the cerebral skull laterally of the crista (11) and the costa (2) and medially of the connection of the crista (13) on the one hand and the joining-point of the costa (2) and the crista (12) on the other hand.

A second musculous attachment occurs with a great number of muscle fibres to a strip of about 2 mm width rostrally of the crista (12) and laterally of the most caudal part of the costa (2), which is only a few mm long.

To the region of the roof of the skull more laterally than the area defined above, no muscle fibres are attached, but muscle fibres lie against this region and against the most caudal part of the zygomatic arch; these muscle fibres are, however, attached more dorsally and more caudally to the roof of the skull.

Attachment by means of an internal aponeurosis. This occurs to the aponeurosis (Bt), which is an internal aponeurosis (personal communication). The muscle fibres are slantingly attached to both surfaces. This aponeurosis is directed ventralwards. Rostrally it is about 9 mm, caudally about 12 mm long. Aponeurosis (Bt) is attached to the crista (13).

Attachment by means of an external aponeurosis. This is the case with the aponeurosis (At), which is an external surface aponeurosis (personal communication). The muscle fibres are slantingly attached to the ventral surface of the aponeurosis. This aponeurosis covers the entire dorso-lateral surface of the musculus temporalis. The strong and thick aponeurosis (At) is attached to the crista (11), the costa (2) and the crista (12). Rostrally, where the muscle fibres bend ventralwards, the aponeurosis extends rostralwards over the frontale, over the zygomatic arch and over the eye.

1b. Musculous attachment. This occurs to an excavation on the medial surface of the processus ascendens of the lower jaw, laterally of the line (2) and more caudally as far as behind the third molar.

Attachment by means of an internal aponeurosis. This occurs with the aponeurosis (Ct), which is at least for its larger part an internal aponeurosis (personal communication). In the more dorsal and caudal parts of the aponeurosis (Ct) the muscle fibres are slantingly attached to both surfaces; in the caudal extension of the aponeurosis the muscle fibres are also slantingly attached to both surfaces; in the ventral part of the aponeurosis, however, the muscle fibres are slantingly attached to the medio-caudal surface only (this ventral part lies superficially). At its dorsal top this aponeurosis (Ct) has a caudalward extension over the caudal part of the zygomatic arch from a far caudal point on the ventral surface of the zygomatic arch to the wall of the cerebral skull and over the roof of the skull as far as a point dorsally of the external auditory aperture. This caudal extension has an irregular form; its maximal breadth is about 5 mm. The aponeurosis itself extends a few mm rostralwards and then bends medialwards. The aponeurosis (Ct) is attached to the crista (14) and to the most dorsal part of the fossa (3), from the top of the processus coronoideus about 2 mm ventralwards.

Attachment by means of an external aponeurosis. This occurs with the aponeurosis (C't) which is an external aponeurosis (personal communication). On this surface aponeurosis (C't) the muscle fibres are slantingly attached only to its lateral surface. The aponeurosis (C't) may be considered as the caudal continuation of the rostro-medial part of the aponeurosis (Ct). Rostrally the aponeurosis (C't) is about 17 mm, caudally about 9 mm long. The aponeurosis (C't) is attached to the line (2).

2a. Surface of the area of attachment. The two areas of musculous attachment belong to the dorsal surface of the cerebral skull, which curves smoothly in a latero-ventral direction showing a vaulted surface. Rostrally this vaulted surface has its lateral termination in the crista (13), caudally the vaulted surface ends at the base of the crista (12). Rostrally from this crista (13) the cerebral skull is directed about perpendicularly ventralwards.

The costa (2) to which the aponeurosis (At) is attached, commences at the caudal end of the roof of the skull, about 5 mm from the median. It runs rostralwards on the roof of the cerebral skull in an S-shaped curve: first a little medially (distance about 3 mm from the median), then it bends laterally (greatest distance about 5 mm from the median), then it bends to rostro-medial and finally the left and the right costae (2) join in the median.

The crista (11), to which the aponeurosis (At) is attached, runs rostrally in the median from the point where the left and the right costa (2) join in the median.

The crista (12), to which the aponeurosis (At) is attached, runs from the caudal end of the costa (2) and latero-ventrally to the osseous external auditory aperture. This high crista (12) is about 12 mm long, ventrally about 2 mm high and dorsally about 1 mm high.

The crista (13), to which the aponeurosis (Bt) is attached, is a rather sharp edge, lying on that rectangle side which is directed caudalwards of a rectangular ridge. This ridge lies in the dorso-caudal border of the orbita and juts out in rostro-lateral direction from the roof of the cerebral skull.

2b. Surface of the area of attachment. This area for musculous attachment on the medial surface of the processus ascendens of the lower jaw, laterally of the line (2) and more caudally as far as behind the third molar, is an excavation. The medial plane of the rostral part of the processus ascendens, thus ventral from the processus coronoideus, is concave. The caudal border of the excavation on the medial surface of the processus ascendens is constituted by the thicker part of this processus which contains the root of the incisor and runs obliquely rostro-ventrally from the processus condyloideus to the bony covering of the roots of the third molar.

The crista (14), to which the aponeurosis (Ct) is attached, forms the sharp rostral edge of the processus coronoideus.

The most dorsal part of the fossa (3), to which the aponeurosis (Ct) is attached, runs from the top of the processus coronoideus about 2 mm ventralwards. At the sharp top of the processus coronoideus the fossa (3) and the crista (14) join dorsally.

The line (2) runs on the medial side of the thin bone of the processus ascendens of the lower jaw and runs from the ventral starting-point of the crista (14) caudalwards.

3. Mutual course of the muscle fibres. This course is related to the characteristic curved form of the muscle: the muscle fibres run rostralwards and there bend ventralwards.

Heading XXIX: muscles of uncertain categories

In the lists given above a number of examples are lacking, though they are given in the papers mentioned. The description of these examples does not go into such details that any of the categories, distinguished above, distinctly emerges. Among them are a number of muscles, for which it was impossible to determine the category exactly, though the material was in good condition. The reason for this can be that the muscle is too small or too thin and that the way of attachment is too minute (DULLEMEIJER, personal communication). That is the reason why *e.g.* in the paper by DULLEMEIJER (1956a, 1956b) on *Vipera berus* (L.) no indication is given of the detailed character of the way of attachment of some thin muscles or of some minute way of attachment. In such cases a more detailed investigation seems necessary to decide whether a musculous attachment, an internal aponeurosis, an external aponeurosis, an internal tendon or an external tendon is present. On the other hand we have to keep in mind that the distinction between musculous, aponeurotic or tendinous attachment arose from macroscopical investigation and that on a microscopical or at any rate on a histological basis the same distinction would not have emerged (see p. 18).

The cases in which it was impossible to incorporate very small muscles with a very minute way of attachment into any of the categories mentioned above, are the following.

(H XXIX) i. *Vipera berus* (L.) (Serpentes; Reptilia) (personal communication by Dr. P. DULLEMEIJER)

a. Musculus adductor mandibulae internus pseudotemporalis

(DULLEMEIJER, 1956a, pp. 18, 106; 1956b, pp. 404, 492)

This muscle runs a) from the cerebral skull, caudal to the processus postorbitalis, b) to the lower jaw.

1a. Musculous attachment. This occurs to the cerebral skull.

1b. Attachment. The attachment to the crista formed by the extension of the lower jaw by means of an aponeurosis is of uncertain character.

2a. Surface of the area of attachment. This area on the cerebral skull is very small: 0.5 × 0.1 mm; it is very probably rounded.

2b. Surface of the area of attachment. This area of the aponeurosis on the crista of the lower jaw is very narrow.

b. Musculus protractor quadrati

(DULLEMEIJER, 1956a, p. 23; 1956b, p. 409)

This muscle runs a) from the basisphenoid on the ventral surface of the cerebral skull, b) to the quadratum.

1a. Attachment. The attachment to the transverse crista on the basisphenoid by means of a short aponeurosis is of uncertain character.

1b. Musculous attachment. This occurs to the quadratum.

2a. Surface of the area of attachment. This area to the basisphenoid is very narrow and relatively long.

2b. Surface of the area of attachment. This area on the quadratum is narrow and in my opinion perhaps rounded; this musculous attachment to the quadratum could also be on a surface with a slight excavation (see 1956a, p. 106; 1956b, p. 492).

3. Mutual course of the muscle fibres. The muscle fibres lie in the plane of the flattened surface of the quadratum; they run perpendicularly to the longitudinal axis of the quadratum (1956a, pp. 23, 86, fig. 17; 1956b, pp. 409, 472, fig. 17; personal communication).

c. Musculus retractor vomeris

(DULLEMEIJER, 1956a, pp. 23-24; 1956b, pp. 409-410)

This muscle runs a) from the cerebral skull in the caudo-ventral corner of the orbita, b) to a short conical extension on the most ventro-caudal point of the vomer, medial to the palatinum.

1a. Musculous attachment. This occurs to the cerebral skull.

1b. Attachment. The attachment to the extension of the vomer by means of a little tendon is of uncertain character; this extension of the vomer is also called a spina (1956a, p. 106; 1956b, p. 492).

2a. Surface of the area of attachment. This area on the cerebral skull is triangular; it is situated in the caudo-ventral corner of the orbita and it is the rostral part of a small, rather deep groove.

2b. Surface of the area of attachment. This area on the extension of the vomer is not described in detail.

3. Mutual course of the muscle fibres. This course shows the fibres diverging from the tendon on the vomer to the cerebral skull.

d. Musculus depressor mandibulae

(DULLEMEIJER, 1956a, pp. 25-26, 63, 65; 1956b, pp. 411-412, 449, 451)

This muscle runs a) from the quadratum and from the dorsal surface of the cerebral skull, b) to the lower jaw.

1a. Musculous attachment. This occurs to the latero-caudal surface of the quadratum.

Attachment by means of an aponeurosis of uncertain character. This takes place to a crista lying on the dorsal surface of the cerebral skull. The aponeurosis is attached to the very short medial part of a crista which runs transversely on the roof between the supratemporalia.

1b. Musculous attachment. This occurs on the processus retro-articularis caudally to the articulation of the lower jaw with the quadratum; on the whole the area of attachment is almost quadrangular dorsal and on the caudal plane of this processus, the latter showing the shape of a rounded quadrangle.

2a. Surface of the area of attachment. This area on the quadratum is probably a rounded surface; it does not seem improbable that it shows a slight excavation (see 1956a, p. 106; 1956b, p. 492). The place of attachment of the aponeurosis is a short crista.

2b. Surface of the area of attachment. In my opinion this area on the dorsal plane of the lower jaw is saddle-shaped, that on the caudal plane spherical.

3. Mutual course of the muscle fibres. This course is related to the fact that the muscle is indistinctly divided into two parts. The rostral part runs from the quadratum to the dorsal, and partly to the caudal plane of the processus retro-articularis. The muscle fibres run in the plane of the flattened surface of the quadratum parallel to the longitudinal axis of the quadratum (1956a, p. 86; 1956b, p. 472; personal communication). The caudal part of the muscle runs from the cerebral skull to the caudal plane of the processus retro-articularis. This caudal part is attached to the cerebral skull by a comparatively long tendon (in one case the tendon was very short).

e. Musculus mylohyoideus

(DULLEMEIJER, 1956a, p. 29; 1956b, p. 415)

This muscle runs a) from the lower jaw, b) to the tongue-bone.

1a. Attachment. This attachment to the lower jaw occurs by means of the common aponeurosis of a number of muscles. As this aponeurosis continues on the lateral surface of the periost to which it is strongly connected and tangentially attached, it is in my opinion probably an external aponeurosis.

1b. Attachment. This attachment to the tongue-bone occurs by means of the perichondrium, of which it is uncertain, whether it is a musculous attachment or not.

2a. Surface of the area of attachment. This area of the aponeurosis is situated on the very narrow ventral ridge of the dentale.

2b. Surface of the area of attachment. This area on the tongue-bone is very probably a rounded surface.

3. Mutual course of the muscle fibres. This is such that the muscle fibres are attached by different angles, which is possibly the cause that the muscle could be separated into three parallel bundles in some cases.

(H XXIX) ii. *Crotalus atrox* Baird & Girard and *Crotalus terrificus* Laur. (Serpentes; Reptilia)

a. Musculus retractor vomeris

(DULLEMEIJER, 1959, p. 907)

The main differences with this muscle in *Vipera berus* (L.) are the following.

1a. Attachment. This attachment takes place to the most caudal part of a crest that forms the caudal and medial border of the orbita; this crest is formed by the lateral edge of the parasphenoid; this way of attachment is tendinous.

1b. Attachment. This attachment to the vomer is also tendinous; this tendon is considerably shorter than in *Vipera*.

b. Musculus depressor mandibulae

(DULLEMEIJER, 1959, p. 908)

The main differences with this muscle in *Vipera berus* (L.) are the following.

1b. The attachment of this muscle to the lower jaw in *Crotalus* differs from that in *Vipera* in not being entirely musculous; it is partly also aponeurotic; it is a short narrow lateral aponeurosis, attached to the lateral edge of the dorsal broadening of the lower jaw.

(H XXIX) iii. *Bitis arietans* Merrem (Serpentes; Reptilia)

a. Musculus depressor mandibulae

(DULLEMEIJER, 1959, p. 938)

The main differences of this big muscle with this muscle in *Vipera berus* (L.) are the following.

2a. Surface of the area of attachment. The necessary size for the attachment is found not only on the quadratum but also on the fascia of the musculus adductor mandibulae externus profundus.

2b. Surface of the area of attachment. The necessary size for the attachment is found on the far extended processus articularis of the lower jaw.

(H XXIX) iv. *Trimeresurus albolabris* Gray (Serpentes; Reptilia)

a. Musculus depressor mandibulae

(DULLEMEIJER, 1959, pp. 939, 958)

The main differences with this muscle in *Vipera berus* (L.) are the following.

2a. Surface of the area of attachment. This area is found on the quadratum only; it shows an enlarged place of attachment on the dorsal part of the quadratum, so that the caudal part of the muscle is not to be distinguished from the rostral part.

(H XXIX) v. *Anas platyrhyncha platyrhyncha* (L.) (Anseres; Aves)

a. Musculus geniohyoideus

(Davids, 1952, pp. 537-538)

This muscle runs a) from the lower jaw caudalwards, b) to the epibranchiale of the hyoidean cornu.

1a. Attachment. This occurs to the medial surface of the lower jaw in an aponeurotic way to a linear crista.

1b. Attachment. This occurs to the hyoidean cornu by enveloping the epibranchiale.

(6) (c) General conclusions about correlations in the conditions realized in nature

The number of examples given above is too small to allow of general conclusions about the value of the correlations between the five said points (1. the way of attachment of the muscles to the skull; 2. the forms of the projections, deepenings and undulations of the surface of the skull; 3. the mutual course of the muscle fibres; 4. the parallel or non-parallel position of the surfaces carrying the places of attachment of muscles; 5. the opposite or non-opposite position of the surfaces carrying the places of attachment of the muscles).

In a very few cases only details are known about the points 4 and 5 and even also about point 3.

In the examples given much detailed information is supplied about the points 1 and 2, but the number of examples is far too small. From many larger systematic groups too few examples are known.

Consequently we do not know the scientific value of the fact that in our material of birds aponeuroses are attached to cristae and in Mammalia to cristae or to fossae or to "lines" (Van Vendeloo, 1953, pp. 275/276).

(iii) (7) Individual variability

Among individuals of the same species there is a variability in anatomical characters, even in the shape of the muscles, in the way of attachment, in the development of the projections *etc.* on the surface of the skull.

In a number of examples we mentioned such differences. Sometimes the variability led to classing the way of attachment in different individuals under different headings, as distinguished above.

A general remark as to this variability is made for *Anas platyrhyncha platyrhyncha* (L.) by DAVIDS (1952, p. 534), who states that, as to its form and as to the dimensions of its parts, the occipital plane shows a rather great variability, but that there is still a correlation between the osseous surface and the attachment of the muscles.

We may give the following examples about individual variability.

Examples: (1) In some cases in *Sphaeroides oblongus* (Bloch) the variation in the shape of a muscle observed in the comparative study, was found to be dependent on the size of the fish, *e.g.* the thinness of the rostral part of the musculus levator arcus palatini (SARKAR, 1960, p. 97).

(2) In *Crotalus viridis helleri* DULLEMEIJER, 1958, p. 82) the processus postorbitalis in big specimens is relatively expanded at the base serving for the larger area of attachment of the musculus levator pterygoidei; from a dorsal view the outline of the cerebral skull is much more curved in the older specimens than in the younger ones owing to the size of the processus postorbitalis; in these big specimens also cristae are to be found on the cerebral skull (DULLEMEIJER, 1958, p. 82).

(3) In *Phasianus colchicus* L., in a few cases, the groove (su.) on the lateral surface of the lower jaw does not reach as far as the processus mandibularis externus, but its place is taken by the slightly developed crista (13), extending in the continuation of the groove (su.) and also incorporated by means of aponeurosis (13) in the attachment of the musculus adductor mandibulae posterior (FUCHS, 1954, pp. 455-456, 457).

(4) In *Phasianus colchicus* L. the aponeurosis (12), which as a rule is a surface aponeurosis, in some cases shows a very narrow margin along the dorsal border, which bears muscle fibres on both surfaces (FUCHS, 1954, p. 457).

(5) In *Podiceps cristatus* L. individual differences in the size and shape could be stated of the two strips on the surface of the regio deltoides on the caudo-latero-ventral side of the neurocranium; here the surface makes an angle which is practically zero, so that there does not occur an attachment of muscle fibres (BAMS, 1956, p. 88).

(6) In *Podiceps cristatus* L. in several individuals a separate part of the musculus depressor mandibulae could be distinguished at its rostral side; perhaps it is a rudiment of a formerly more important part of a complex musculus depressor (BAMS, 1956, p. 89).

(7) In *Podiceps cristatus* L. the aponeurosis (X) of the musculus adductor mandibulae externus et posterior is individually rather variable in relation to strength and size; generally it is stronger in older individuals than in younger ones; especially in individuals in which the aponeurosis is strongly developed, the rostral part is rather extended, *viz.* rostrally of the processus temporalis, along the crista postorbitalis; this extension may amount to several mm (BAMS, 1956, p. 92).

(8) In *Podiceps cristatus* L. the two parts, a rostral and a caudal one, of the musculus adductor mandibulae externus profundus, in most specimens are not fused with each other, but distinctly separated; in other specimens they are fused (BAMS, 1956, p. 248).

CHAPTER (II)

TOPOGRAPHICAL-ANATOMICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

(II) (i) *Introduction*

We have already discussed a number of features in the field of topographical anatomy. We mention the topography of the surface of attachment in relation to the carrying surface and the topography of the surface of attachment as regards muscle fibres and aponeuroses. Other topographical relations still remain to be dicussed in detail.

As we have already stated above, we have to distinguish the general surface of the skull, the carrying surface, the interlinked elements, such as projections, deepenings and undulations of the surface of the skull and such as aponeuroses and tendons, and the muscle fibres.

(II) (ii) *The general conditions with respect to the topographical-anatomical relations*

With this topographical-anatomical examination a number of questions come up for discussion, which can be grouped under the following seven headings.

(ii) (1) The topography of each surface of attachment and of each interlinked element on the skull of each muscle in relation to the surface of the skull as a whole

With this it is determined for each surface of attachment and for each interlinked element on which skull-element, on which functional skull-component it is situated and also in particular whether it is rostral or caudal or in between on the skull, whether it is dorsal or ventral or lateral there, and in all cases to which side it is situated.

In the case of the topographical indications, as dorsal *etc.*, terms designating a direction, as for instance a plane "facing" in a certain direction that means the direction of the perpendicular to this plane, Burggraaf & Fuchs (1954, pp. 286-287) use a term like rostro-ventro-lateral in such a way, that the last of the two or three components of the composite term indicates the main direction, the forelast the secondary component of the direction while the first part designates the smallest deviation from the following three basic planes, which are at right angles to each other (the "horizontal", the sagittal and the "vertical" plane).

Discussing the different types of muscles in the head, we have seen above (p. 57) that muscle-ends can also be attached to skeletal parts outside the head and to soft parts either in the head and/or outside the head.

An exact determination of the topographical situation is of importance to understand the function of the muscle and *vice versa* and to understand the position (participation) of the muscle in the architecture or structure of the head.

(ii) (2) The topography of each surface of attachment and of each interlinked element on the skull of each muscle in relation to the surface of the skull in that region

Confining ourselves here to the above-mentioned surface of attachment and interlinked element as far as they are a surface or an element of the skull we may give the following general remarks.

In this connection it is of decisive importance whether the surface of attachment or the surface of implantation of the interlinked element is small or large.

With a very small surface of attachment and with an interlinked element we shall nearly always have to do with an internal or external aponeurosis or tendon, rarely with a musculous attachment. In these cases no general rule can be given about the relation of the positions neither of these aponeuroses and tendines nor of the surfaces of attachment and the interlinked elements to the carrying surfaces and thus neither on the relation of the positions of the said surfaces of attachment and of the interlinked elements to the surface of the skull in that region, if this latter surface is not the same as the carrying surface.

With a very large surface of attachment we shall nearly always have to do with a musculous attachment. In these cases no general rule can be given about the relation of the positions of this surface to the carrying surface and thus neither on the relation of the positions of this surface of attachment to the surface of the skull in this region. In the case that the skull as a whole displays a single surface-form the large surface of attachment will be taken up in the general skull-form.

Special cases worth mentioning are those in which the attachment of a muscle is correlated with a certain shape of the adjoining neighbourhood of the area of attachment of the muscle on the skull.

Examples: (1) It seems plausible to consider the thickened ventro-medial ridge of the lower jaw in *Vipera berus* (L.) as a resistance to the pressure caused by the musculus adductor mandibulae internus pterygoideus with its almost tangentially attached fibres; this muscle causes a strain during the swallowing in almost the same direction as the longitudinal axis of the lower jaw (DULLEMEIJER, 1956a, p. 92; 1956b, p. 478).

(2) We may state that both wings, constituting the caudal part of the pterygoid in *Vipera berus* (L.), which make an angle of about 120° with each other, play a part in the resistance against bending (flexion), caused by the contraction either of the musculus adductor internus pterygoideus accessorius attached to one of the wings, or of the musculus protractor pterygoidei attached to the other wing, if we suppose that these two muscles do not work simultaneously; each wing runs in the direction of the muscle force of one of the muscles, forming a maximum resistance against bending (flexion) (DULLEMEIJER, 1956a, p. 83; 1956b, p. 469; see 1959, pp. 954-955 for *Crotalus*, *Trimeresurus* and *Bitis*).

A comparison of the development in systematically related species with distinctly different conditions in the relative size of the surfaces of attachment, shows the details of a different development in the topographical relations. This can be due to a difference in the size of the areas of attachment or to a difference in the size of that part of the surface of the cerebral skull or to both.

Examples: (1) The topographical conditions of the areas of attachment of skull muscles in *Columbia palumbus palumbus* L. are different from those in many other birds, as the areas of attachment of the muscles of the jaws in *Columba* occupy only a small part of the total surface of the skull, as the muscles themselves are only slightly developed and as moreover the cerebral skull is relatively extensive in caudal and lateral directions (ROOTH, 1953, p. 263).

(2) The topographical conditions of the area of attachment of the musculus splenius capitis on the caudal wall of the skull in *Phasianus colchicus* L. and in *Perdix perdix* L. are different, owing to the difference in size of the area of attachment. This area of attachment in *Phasianus* is relatively larger than in *Perdix* (assuming that the part of the total surface of the caudal wall which is not available for the attachment of cervical muscles, is relatively about equally extensive in *Perdix* and in *Phasianus*). Not only the relative size but also the position of the place of attachment of the musculus splenius capitis is different in *Phasianus* from that in *Perdix*. The caudal wall of the skull in *Phasianus* is relatively high and narrow and in *Perdix* relatively low and broad. This difference in the shape of the caudal wall has its consequences with respect to the position of the places of attachment of the various cervical muscles (DEN BOER, 1953, pp. 338-339). The greater breadth in relation to the height on the caudal surface of the skull entails that the place of attachment of the musculus splenius capitis is situated in *Perdix* more laterally on the skull than in *Phasianus* (DEN BOER, 1953, pp. 344-345).

(ii) (3) The relative topography of the surfaces of attachment and of the interlinked elements on both ends of a single muscle in regard to the skull as a whole

The relative topography of the surfaces of attachment and of the interlinked elements on both ends of a single muscle in regard to the skull as a whole, is widely divergent in various muscles. Some muscles run from front to back in the skull, others go from top to bottom, yet others from lateral to medial in a horizontal plane, *etc.* These relative positions of the surfaces of attachment and of the interlinked elements of both ends of various muscles in regard to the skull as a whole can be told from the place and the position of the central axis of the muscle in the skull.

In the enumeration of the different types of muscles in the head, given above (p. 57 *sq.*), we have seen that muscles in the head can also run from the skull to skeletal parts outside the skull, from the skull to soft parts in or outside the head and that they can also run from soft parts in the head to other soft parts in the head, or to skeletal or non-skeletal parts outside the head.

The relative positions of the surfaces of attachment and of the interlinked elements referred to and the place and position of the axis of the muscle are closely linked up with the function of the muscle.

(ii) (4) The relative topography of the surfaces of attachment and of the carrying surfaces on both ends of a single muscle in regard to each other

We will confine ourselves here to the above-mentioned two surfaces as far as they are surfaces of the skull.

The relative positions of the surfaces of attachment and of the carrying surfaces on both ends of a single muscle in regard to each other are widely different in various muscles.

To a large extent these differences are connected with the question whether the two surfaces of attachment cover a very small surface, or whether at one end the surface is very small and at the other end covers a large surface, or whether the two surfaces of attachment are large, in which the question enters whether the two surfaces are equally large or differently large. Furthermore, these differences are bound up with the fact whether the skeletal surface of attachment is convex, concave or flat on one or on both sides, whether it has the shape of a crista or a spina, *etc.*

(4) *α*) In the cases of both surfaces of attachment being small

Then the relative positions of the surfaces of attachment and of the carrying surfaces of these two surfaces of attachment can be widely divergent in various muscles. These surfaces of attachment and their carrying surfaces can be parallel, but they can also take a very different position in space.

If the surfaces of attachment on these carrying surfaces are little spots (convex, concave or flat) and if we assume the attachment to be musculous on these little spots, they will, as to their general positions, usually be about parallel, or rather: the middle perpendiculars on these little surfaces of attachment will be continuations of each other, as these perpendiculars will coincide with the axes of the muscles attached to them. The little surfaces of attachment may coincide with their carrying surfaces in the case that the said middle perpendiculars are at the same time perpendicular to the carrying surfaces. Such will, as a rule, not be the case, however.

If the two surfaces of attachment are on the free edge of a crista, this free edge will be parallel to the surface of the carrying surface for each end, and therefore there will usually be no connection between the position of the free edges of the two cristae. It makes no difference whether the attachment to the cristae is musculous or aponeurotic.

If the two surfaces of attachment are spinae, the axes of both will usually be continuations of each other. These axes can be perpendicular to the carrying surface, but as a rule such will not be the case. Here, too, it makes no difference whether the attachment to the spinae is musculous, or takes place by means of an external or an internal tendon.

(4) β) In cases where one surface of attachment is small and the other large

Then the relative positions of the two surfaces of attachment and of the carrying surfaces will be very different. In principle the position of the small surface of attachment and of its carrying surface will be independent of that of the large surface of attachment and of that of its carrying surface.

Before discussing the mutual topography of the two surfaces of attachment and of the two carrying surfaces, we will consider how many possibilities there are. Assuming that a small surface of attachment is situated on a smooth flat spot (and taking the convex, the concave and the flat form as one), on a crista or on a spina and that the large surface of attachment is a smooth convex, a smooth concave or a smooth flat spot, then we have nine combinations. Assuming further that the attachment of muscle fibres can occur on a crista as well as on a spina in three forms (musculous, external aponeurosis, internal aponeurosis), then we get twice six combinations more, so that they number 21 in total. If we assume that the muscle fibres can diverge or converge or run parallel, there would be 21 x 3 = 63 combinations. Of these 63 combinations some will not occur, as *e.g.* a muscle bundle which converges from a small surface, a crista or a spina, to which it would be attached musculously, to a large convex, concave or flat surface of attachment. An attachment to an internal aponeurosis will not occur either, if in those cases the muscle bundle would have to converge to a large convex, concave or flat surface of attachment. Except in the case of converging muscle fibres, a muscle with parallel muscle fibres will no more occur in any of these cases. For the said reasons 30 combinations will be lacking.

The remaining 33 combinations are no doubt possible or likely. We assume, therefore, that muscles with diverging muscle fibres will occur, from the seven types of small surfaces of attachment, each to the three forms of large smooth surfaces of attachment, numbering 21 in total. We assume also muscles with converging as well as parallel muscle fibres from external aponeuroses on cristae and spinae, likewise to each of the three forms of large smooth surfaces of attachment; they number 12 in total.

Of these 33 as possible or likely remaining combinations the central axis of the muscle will usually be perpendicular to the tangent plane in the centre of the one small surface of attachment, if it is a smooth flat or convex or concave spot. In the case that the small surface is a spina, the central axis of the muscle will be a continuation of the axis of a spina. This muscle-axis will be able to make a different angle with the free edge of a crista, which free edge will as a rule run parallel with the surface of the carrying surface. The position of these small surfaces of attachment is highly independent of that of the carrying surfaces. As the central axis of the muscle can make a widely different angle with the large smooth surface of attachment, which may be convex, concave or flat, and as the same may occur with the carrying surface too, this implies that no generally applicable conclusion can be drawn from the relative position of the surfaces of attachment and of the carrying surfaces on both ends of a single muscle which shows a small surface of attachment and a large surface of attachment.

(4) γ) In cases where both surfaces of attachment are large

Then the relative positions of these two surfaces of attachment and those of their carrying surfaces can be widely divergent in various muscles. They can be parallel, but they can also take highly varying positions in space.

Before discussing the mutual topography of the two surfaces of attachment and of the two carrying surfaces, we will consider how many possibilities there are.

(a) As a first case of a large surface of attachment at both muscle-ends we assume that there is musculous attachment to both muscle-ends on the large surfaces of attachment. When we distinguish three kinds of surfaces of attachment (convex, concave, flat), we can distinguish $3 + 2 + 1 = 6$ different combinations. If besides this we distinguish muscles with a diverging, a converging and a parallel course of the muscle fibres, we would expect $6 \times 3 = 18$ different combinations, of which there remain only fifteen, if we subtract the three combinations which occur twice (convex-convex, concave-concave and flat-flat with a diverging and a converging course of the muscle fibres are equal) (DEN BOER, 1953, p. 472, distinguished 9 instead of 15 combinations).

Restricting ourselves to the simplest case in which the central axis of the muscle coincides with the perpendiculars on the tangent planes in the centres of the two surfaces of attachment, we find these tangent planes in the centres of these surfaces of attachment to be parallel to each other. Dependent on the form of the surface of attachment and the course of the muscle fibres, the latter will make a right or an acute angle with the surface of attachment. In the case of an acute angle, this angle may vary in size, dependent on the place of attachment and the curve radius of the convex or concave surface of attachment. The ratio of the relative sizes of the two surfaces of attachment in this simple case depends on the course of the muscle fibres (parallel, diverging or converging) and on the shape of the surface of attachment (convex, concave or flat). Besides this simplest case there are also complicated cases.

A first complication can occur owing to the central axis of the muscle not being perpendicular to the parallel surfaces formed by the tangent planes in the centres of the surfaces of attachment of the muscle. The muscle fibres then make a different angle with the surface of attachment.

A second complication can arise from the fact that the said tangent planes at both muscle-ends do not run parallel. In the latter case, with a parallel course of the muscle fibres, the two surfaces of attachment will not be equally large in principle.

(b) We now take a second case of a large surface of attachment at both muscle-ends, as given through attachment to a crista on both sides, and assume the attachment of muscles to take place through a musculous attachment, through a groove-shaped external aponeurosis or through a plate-shaped internal aponeurosis. Of this there are also $3 + 2 + 1 = 6$ different combinations possible. If we consider muscles with diverging, converging or parallel course of the muscle fibres, we may assume up to $3 \times 6 = 18$ different combinations. Of these, again, two combinations occur twice (flat - flat: diverging and converging; external aponeurosis — external aponeurosis: diverging and converging), while 6 combinations are impossible (flat - internal aponeurosis; parallel - diverging; external aponeurosis - internal aponeurosis; diverging - parallel; internal aponeurosis - internal aponeurosis; diverging - converging). This case, too, can be elaborated on the point of the relative positions of the two surfaces of attachment.

A number of other cases could be worked out in the same way.

Not only when considering different muscles do we find that the relative positions of the surfaces of attachment can widely diverge at both muscle-ends, but in some cases this can also occur with a like muscle, which depends on the degree of contraction of the muscle.

When a muscle contracts, two cases may be possible (see DEN BOER, 1953, p. 472):

A. the two places of attachment change their position parallel to each other;

B. the two places of attachment do not change their position parallel to each other, but one place of attachment is rotated round a turning-point or turning-axis in relation to each other. Here two cases may occur:

a. the centre of rotation is situated within one of the areas of attachment;

Examples: (1) The musculus splenius capitis in *Phasianus colchicus* L. and in *Perdix perdix* L. (DEN BOER, 1953, p. 472).

b. the centre of rotation is not situated in either of the areas of attachment, but lies outside of either of these areas.

Examples: (1) The cervical muscles in *Phasianus colchicus* L. and in *Perdix perdix* L., with the exception of the musculus splenius capitis; there is, however, a distinct difference between the different muscles as to the situation of the centre of rotation and thus also as to the length of the arm and the strength of the forces (DEN BOER, 1953, pp. 472-473).

(ii) (5) The topography of each surface of attachment on the skull of each muscle as regards neighbouring elements of the surface of the skull

This section does not concern the adjoining part of the surface of the skull, which was discussed above under (2), but it concerns elements of or details on the adjoining surface.

In the first place we think of elements or surface-details, such as perforations for nerves and blood-vessels, adjacent to a surface of attachment for a muscle-end, but we also think of a case such as the bulla auditiva in Mammalia adjacent to the processus paroccipitalis serving for muscle-attachment, and of which the shape, size and position are also determined by the bulla auditiva.

In the second place we have in mind the surfaces of attachment of a second part of the same forked muscle or of another muscle adjacent to the surface of attachment of a muscle examined by us.

(ii) (6) The topography of each surface of attachment on the skull of each muscle with regard to other soft parts, running along or across the surface of the skull

Here are concerned nerves, blood-vessels, ligaments, *etc.*, displaying in their courses along or across the surface of the skull a certain position in relation to the surfaces of attachment of the muscles.

(ii) (7) The topography of each surface of attachment on the skull of each muscle as regards its muscle fibres and aponeuroses

In what was said above, this subject was already discussed, so that a summarizing repetition appears unnecessary.

Here are concerned large and small surfaces of attachment, *viz.* large flat smooth, large convex smooth, large concave smooth surfaces, small flat smooth, small convex smooth, small concave smooth surfaces, cristae, spinae and other projections on the surface, hollowings and sinkings in the superficial layer of the skull, *etc.*

We have to deal separately with some general aspects of the topography of the surfaces of attachment mentioned as regards their muscle fibres in the case of a musculous attachment and with the topography of the surfaces of attachment mentioned as regards their muscle fibres and their aponeuroses and their tendons in the case of an aponeurotic attachment.

Specially at issue are these topographical relations in the cases of a tendinous or an aponeurotic attachment of muscle fibres to which MOLLIER (1937) has paid much attention. MOLLIER (1937, pp. 163-165) distinguishes the following series of elements: (1) the muscle fibres; (2) next to these the tendon or the aponeurosis; (3) the basis of the tendon or of the aponeurosis, either (3a) showing a transition in the periost (in the case of a periost-"cuff"; the slipping off of this "cuff" is prevented by means of the successive series: fibres of Sharpey - bone), or (3b) showing a direct inward penetration ("Einstrahlung") in the bone tissue (especially on bony rough surface elements ("Rauhigkeiten") and on bone cristae), or (3c) showing a combination of the two.

In the case of an aponeurotic attachment to two bony elements which by contraction of the muscle change the angle between these two bony elements, the angle between tendon and bony element of attachment at both areas of attachment will alter too. Still there is no destruction ("Zerstörung") of the tendon tissue thanks to the structure of the tissue of the tendon as well as to the shape of the tendon on the transitional territory of tendon and bone (MOLLIER, 1937, p. 163). In such cases MOLLIER (1937, pp. 163-165) distinguishes within the tendon of such muscles: (a) a free part of the tendon, being adjusted to the direction of the tension of the muscle; (b) a direction-bound part of the tendon; its direction must follow that of the bone. If in consequence of the bending of a complex skeletal part, the parts (a) and (b) of the tendon do not lie in the same direction any more, a "harmful angle" or an "unprofitable angle" ("schädliche Winkel") (MOLLIER, 1937, p. 168) has arisen and spots which functionally incur risks ("gefährdete Stellen") are present on the transition of tendon and bone (MOLLIER, 1937, p. 170). Such a damaging influence making great demands ("schädigende Beanspruchung") on such transitional places of tendon to bone, on such "unprofitable angles" is eliminated in the following ways (MOLLIER, 1937, pp. 170, 173 *sq.*, 193 *sq.*): (1) by means of a tendon-fan ("Sehnenfächer") or fan-shaped spread of the fibres ("fächerförmige Ausbreitung der Fasern"); this fact entails that the fibre bundles approach the bone under different angles; (2) in the case of muscle-tendon-systems which are not freely extended over their whole length between two places of attachment but which in their course are turned away ("abgelenkt") from the straight course by means of a special mechanism for turning away ("Ablenkungsvorrichtung") as *e.g.* rollers or pulleys for turning away ("Ablenkungsrollen") on one side and a decisive stretcher ("massgebende Strecke") on the other side.

It is probably according to the principle of MOLLIER that the effective functioning of a muscle fibre is only possible when it is attached to the surface at a special angle - or an angle slightly varying from this optimal angle - and so it may be expected that the muscle in which nearly all the muscle fibres are attached to the surface at the same angle, will function by contracting all the fibres at the same time. This applies to the medial part of the musculus rectus capitis ventralis in *Perdix perdix* L. which will function only when the head is kept in one (or a few) special position(s) (DEN BOER, 1953, p. 468).

It may be expected according to this same principle of MOLLIER that the muscle in which the muscle fibres are attached at greatly varying angles, will function by contracting only part of the muscle fibres at a time, *viz.* those that are at the most favourable angle to the surface, dependent on the position of the head in relation to the neck at the moment of action. This applies to the medial part of the musculus rectus capitis ventralis in *Phasianus colchicus* L., which will function with any given position of the head (DEN BOER, 1953, p. 468).

An explanation of the functional significance of the crossing of the muscle fibres in a muscle and of the fact that muscle fibres are attached to the bone at different angles is given by this principle of MOLLIER according to DULLEMEIJER (1952, p. 95): it is the overcoming of the "unprofitable" angle. Assuming that a power acting through certain fibres causes the lowest unilateral tension in the connective tissue of the fibres when these fibres are attached to the bone at a certain special angle, then in each particular position of the bone only a part of the fibres will contract, *viz.* those which are directed with that special angle. This contraction brings the bone in another position and consequently another part of the fibres is brought into the most favourable position and will contract, while the first part relaxes. In every case the fibres will have an angle, in which the unilateral tension in the connective tissue of the muscle is low. Within a certain changing of this angle the unilateral tension remains rather low and we may call the area in which this unilateral tension remains low, the angle of deviation. The deviation-angle may be dependent on many factors (DULLEMEIJER, 1952, pp. 95/96).

CHAPTER (III)

ONTOGENETIC EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

Very little study has been made of the ontogeny of the projections, deepenings and undulations of the surface of the skull in relation to the attachment of muscles. Such is also the case with the ontogeny of the aponeuroses and tendons, and with the ontogeny of the muscles and their finer structure.

We know, however, that very generally we can say that the projections, deepenings and undulations of the surface of the skull, which are well-developed in adult specimens, are lacking or are very slightly developed in early stages of development, also in other ontogenetic stages and even in young specimens (see plate 24 a, b, c).

The cristae which do not bear any aponeurotic attachment but in which the sides are covered with musculous attachments, are frequently very low in young animals, whereas in old ones they are of considerable size (DULLEMEIJER, 1958, p. 84).

The study of the ontogenetic development of these projections, *etc.* in connection with the ontogenetic development of the aponeuroses and of the muscle itself in its finer structure gives promise of interesting results.

The ontogenetic development of cristae and spinae may by due to remnants of bone in a particular region where the surroundings have been excavated by muscles (LAKJER's view); this does not seem to be applicable according to SARKAR (1960, pp. 113-114), who mentions that sometimes an aponeurosis is ossified at the base of an aponeurosis, owing to tension, giving rise to such processes as a crista or a spina.

This study of the ontogenetic development is of special interest in those skulls where cartilage changes into ossified cartilage in places where muscles are attached. It is also of special interest in the cases where a dermal bone grows by an enlargement of the basal plate, extending beneath a muscle, whose area of attachment is found on the perpendicular free margin of the upper layers of this dermal bone ("dune-edge" or "dune-rim"-attachment) (COOL, 1952, p. 640) (see this paper on p. 233).

CHAPTER (IV)

FUNCTIONAL-ANATOMICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

(IV) (i) *Introduction*

After our remarks in the general introduction (p. 13) it will be clear that the functional-anatomic examination of the projections, deepenings and undulations of the surface of the skull in relation to the attachment of muscles is very important. As was shown we do not have to do here with conservative characters of elements or with conservative characters of building-stones of the structure, but we have to do with details of elements, *etc.* or with such characters of elements, etc., that will have to be explained from the special requirements made by the functions.

It can already here be stated, that besides certain characters of the form of the elements or of the building-stones, also the structure and the position, or in my opinion more generally the connections, correlations (direct and indirect), relations and integrations of such elements, *etc.* are dependent on the requirements of the functions, as there is not only a correlation between function and form, but also between function and position (DULLEMEIJER, 1956a, pp. 74, 103, 105, 107; 1956b, pp. 460, 489, 491, 493). We can also formulate it in this way that the shape is determined by mechanical and by spatial factors and that the way of determination is mainly dependent on the relation between the positions of the different elements (DULLEMEIJER, 1956a, p. 74; 1956b, p. 460; 1959, p. 944).

With regard to the connections and relations we have to distinguish those within the part of the body studied and those between this part and its adjacent neighbourhood. Dependent on the size of the part of the body studied the internal connections and relations between the elements constituting together this part, play a more or less important role.

The consideration of primary elements may indicate a strict and direct relation between form and function, as primary elements are those elements which are not influenced by surrounding elements and as the forms of primary elements can be understood only in relation to their functions (primary regards one or more of the six properties mentioned by DULLEMEIJER in a later publication (1958, pp. 74/75), as is the case for many properties with the eye *e.g.*

The consideration of secondary elements does not show a simple relation between form and function, the form-function relation not being strict, as secondary elements are those elements which are influenced by surrounding elements, and as the forms of secondary elements can be understood only in relation to their own functions, and to those of the surrounding elements (secondary regards one or more of the six properties mentioned by DULLEMEIJER, as is the case for many properties with the glands *e.g.*) (DULLEMEIJER, 1958, pp. 75/76, 79).

The direct relation between form and function, therefore, may be studied from their simple, strict and direct relation in primary elements and from their complicated non-simple, non-strict and non-direct relations in secondary elements as well as from their indirect relation by the intervention of one of the properties of a neighbouring element. The mentioned properties of neighbouring elements are: shape, build, structure, size, position and function (list of properties by DULLEMEIJER changed a little).

On the aspect of the relation between these six properties of one and the same element and between these properties of surrounding elements of different character, is written in the sense of "relation" (a rather neutral word), but also in the sense of "influence" (a more causal relation) and also in the sense of "requirement" (a rather teleological relation). Thus DULLEMEIJER (1958, p. 85) writes that the influence of the muscle on the bony element may be regarded as the functional requirement of this bony element; it is one of the few cases in which the functional requirement lies directly within the organism (many functional requirements for the elements have an ecological character) (DULLEMEIJER, 1958, p. 85).

Out of the many examples of this mutual influence DULLEMEIJER (1958, pp. 78-84) has given, we draw attention to the following ones. We will concentrate and limit our interest here to the function of the muscle and the relation of this function to other properties.

As to the relation of the function of the muscle to the shape, we cite the following examples. To a functional requirement of the muscle, the shape of the muscle does not bear any relation; the shape is determined by the space in which the muscle lies (in certain cases the space is restricted considerably, mainly by bony elements); in case the space is not restricted, the shape is the consequence of the size and the structure of the muscle (DULLEMEIJER, 1958, p. 81); the function of the muscle very markedly influences the shape, the structure and the size of a bony element (DULLEMEIJER, 1958, p. 84).

As to the relation of the function of the muscle to the structure of the muscle, the latter is partly understandable by its function, partly by the influence on the surroundings (DULLEMEIJER, 1958, p. 81). The structure and the function of a muscle exercises the greatest influence on the surrounding elements, to a less degree it is done by the size of a muscle (DULLEMEIJER, 1958, p. 82).

As to the relation of the function of the muscle to the size of the muscle, there is a direct one to the size of the muscle or to that of various muscles (DULLEMEIJER, 1958, p. 80). The function of lifting the skeletal element to which the muscle is attached shows a direct relation to the length of the muscle (DULLEMEIJER, 1958, pp. 80-81; the extension of the musculus adductor mandibulae externus superficialis in Birds on the cerebral skull and on the os accessorium is mentioned). A large capacity for lifting may be realized by the action of different groups of muscles which work alternately (DULLEMEIJER, 1958, p. 81, who mentions the Viperidae as an example).

As to the relation of the function of the muscle to the position we mention that the function has to be understood partly functionally, partly by the available space allowed to them in a pattern (DULLEMEIJER, 1958, p. 79). The special functional requirement concerning strength and lifting-power, asks a certain space; thus what occurs depends on the space available (DULLEMEIJER, 1958, p. 81). The function of a muscle is independent of the surrounding elements, if the function of a muscle is considered to be a contraction, resulting in the approach of two elements (DULLEMEIJER, 1958, p. 81). If the specific action of a certain muscle is regarded, then the function is dependent on the position of the elements. This phenomenon, however, is of minor importance in understanding the structure of a muscle (DULLEMEIJER, 1958, p. 81).

In the mentioned later published paper DULLEMEIJER (1958) considers the relation of form and function to be part of the broader field of mutual influence of a number of properties, calling them presence, position, size, shape, structure and function. I may call presence "positive size" and I may distinguish within "form in a broader sense" three aspects: structure as finer inner form, build as more rough inner form, and shape as circumference. If I may group these properties under the following headings, we get a) form in a broader sense, thus including 1. shape, 2. build and 3. structure; b) 4. size; c) 5. position and d) 6. function. DULLEMEIJER (1958, p. 77) mentions the mutual influence of his six properties of the influencing element on the same six properties of the influenced element.

From a number of the given examples it follows that also the relation of the six properties in one and the same skeletal element, in one and the same muscle *etc.* is meant. This follows as well from the methods mentioned to analyse and determine the effect of this mutual influence: the comparative method, the theoretical deduction (based on theoretical considerations or calculations) and the experimental approach (DULLEMEIJER, 1958, pp. 77/78), as from the examples treated.

By virtue of the character of anatomy as analytic-atomistic science and also on the ground of the historic development of functional anatomy, form and function of parts of the body, as *e.g.* of organs and complexes of organs, are brought into correlation in this branch of science.

In functional anatomy a synthesis should be sought between the aspect of the form and the aspect of the function of a part of the body examined.

In a very provisional stage of the results of such an examination, the functional anatomic examination will restrict itself to collect facts found in the field of form and facts found in the field of function regularly occurring together.

In a more advanced stage of research in this field it will have to lead to a better understanding of the correlations stated, equally based on a detailed and thorough knowledge of the form and of the function as a result of a profound investigation of both in the same animal species.

In practice, however, the functional-anatomic consideration is applied either by anatomists or by physiologists and the character of the correlation between form and function is seldom object of a serious reflection.

For obvious reasons the anatomist pays greater attention to the form than to the function and he examines the form more thoroughly than the function. This sometimes goes such lengths that no investigations are made as to the function, let alone they are experimentally determined and the function is no more than speculated upon.

In the approach of the relation of form to function by a physiologically trained researcher, an insight based on the investigation of the finer structure of the surface of the skull and of the muscular structure is often lacking. In this physiological line the shape and the structure of a component are considered as a necessary deduction in constructive sense from some biological functions, in other words: the morphological component is considered as a realization of the function (though in practice the investigation is started in the reversed way from the shape and structure to the functions), but in many cases this necessity possesses a certain degree of liberty and other factors must be taken into account (DULLEMEIJER, 1956a, p. 3; 1956b, p. 389; 1959, p. 882; see SARKAR, 1960, pp. 85/86, 115 on the notion of "realization").

As to a better understanding of the character of the correlations of the facts found in the field of form and of function, it seems possible according to DULLEMEIJER (1956a, pp. 3-4, 58-60; 1956b, pp. 389-390, 444-446; 1959, p. 882) to understand a general connection of form and function and to solve the problem of the integrations of form and function and their mutual influences, starting from the given realizations as structural facts.

Such a general connection of form and function is found and is applied at the level of non-typical biological phenomena, where mechanical laws are applicable. At this level there is no separate field of form and of function with a synthesis of the two at the end.

On the subject of muscular build and muscular action on the one hand and skeletal build and functional properties of the tissue of bone and cartilage and of aponeurotic tissue on the other hand, we can get analyzing so far, that we have arrived at the level of non-typical biological phenomena and that mechanical laws are applicable here. In this way it is possible for us to understand at this level the correlation of form and function in the relation between muscles and skeleton (see DULLEMEIJER, 1956a, pp. 74 *sq.*; 1956b, pp. 460 *sq.*).

However great the failures of this approach from two points of view may be and however fundamental our criticism must be, yet in what follows we cannot but accept the actual position, in which some investigators proceed from the form, some from the function; very few only are not forced to proceed from one of these two empirisms.

(IV) (ii) *The relation form-function in a consideration putting the form primarily*

(ii) (1) Introduction

Here the starting-point is the form and one wonders in what way and to what extent this fits in with the function or functions which have been roughly ascertained or which are assumed (for some historical facts see DULLEMEIJER, 1957). Form does not mean outer shape only, but also the gross build as well as the finer structure, whereby also the position comes up for discussion.

With this consideration it is of great influence whether one proceeds from a small part or from a larger part of the body, the latter showing distinct outlines within the whole body. With the larger parts of the body we think of loose skeleton-elements, functional components and the like (DULLEMEIJER, 1956a, pp. 2-3, 60; 1956b, pp. 388-389, 446).

In connection with this and in connection with the character of the various smaller parts of the body, showing distinct outlines within this whole body, we will link our considerations to the following morphological parts:

(2) projections, deepenings and undulations of the surface of the skull (p. 201);
(3) aponeuroses (p. 205);
(4) muscles (p. 212);
(5) bigger parts of the surface of the skull (p. 215);
(6) complicated muscles or muscle systems with a system of aponeuroses (p. 217).

(ii) (2) The functional anatomy of the projections, deepenings and undulations of the surface of the skull

(2) (a) Introduction

We might say that "surface", taken in the sense of a stereometric, sometimes geometric plane, has no biological function. A surface in these senses has no thickness. When, in spite of this, we discuss functions of the elements of the surface of the skull mentioned in the headline, we are well aware that, even with a very thin bone plate, something spatial is concerned, covered by the said elements of the stereometric surface, which for our subject is only a delimitation of something showing the functions to be discussed.

(2) (b) The relation of the form, build, finer structure and position of the projections, deepenings and undulations of the surface of the skull to their mechanical function in the muscular action

Starting from the form, build, finer structure and position of a given area of attachment of a muscle on the surface of the skull, we assume that they are closely related with the strength of the muscular action. In that case there is also a relation to the size of this surface of attachment. An equal muscular strength can act on a large flat surface or on a large crista, but also on a small flat surface, a small spot on a crista and on a spina. Consequently, the action on an equally large surface of the skull will differ and this may explain the differences in the structure of the surface, of the skeletal tissue beneath, of the spinae and of the finer structure of the spinae, *etc.*

The relation of the form, *etc.* of these projections, *etc.* of the surface of the skull to their mechanic function in the muscular action may no doubt be considered as a special case of the general relation of the shape, also the detailed shape of a bony element to the mechanical or physiological factors and the spatial factors (in my opinion better the connections and relations), the way of determination being mainly dependent on the relation between the positions, *etc.* of the different elements. In that case the form, *etc.* of the projections, *etc.* of the surface of the skull has to be considered as the consequence of the constructive influence of mechanical or physiological factors and space or position (or better: connections or relations) (DULLEMEIJER, 1956a, p. 74; 1956b, p. 460; see also BURGGRAAF & FUCHS, 1955, p. 99 on the relative size of parts, processus *etc.* in relation with the mechanical demands imposed on them). The material of which the elements are built generally plays an important role in the realization of the function (DULLEMEIJER, 1956a, p. 75; 1956b, p. 461).

A rather direct relation between the development of the aponeuroses and that of the cristae, strongly developed aponeuroses, occurring on strong, large and very marked cristae and weak aponeuroses, occurring on cristae that are hardly distinguishable as such, is assumed by BURGGRAAF & FUCHS (1955, pp. 98, 99).

Resistance applied against a number of stresses exerted by muscles at different angles attached to a projection, is possible in the case of a projection which shows a shape adapted to various functional requirements (SARKAR, 1960, p. 105).

Examples: (1) The hyomandibular crest in *Sphaeroides oblongus* (Bloch) shows a triangular form in cross section; the top of the triangle is directed lateralwards, the sides of the triangle face rostrally and latero-dorsally respectively; one of the two surfaces of this crest faces rostro-dorsalwards and the other caudo-ventralwards. The rostro-dorsal surface, the rostral arm and the caudo-ventral surface of this crest are the places of attachment of the different muscles (the muscle $A_1m\beta$ and A_2, *etc.*, attached with their different directions and angles of the working-lines of forces acting on this crest; such a bony plate which will resist the bending, will be perpendicular to the working forces and in the same plane (SARKAR, 1960, p. 105).

The mechanical demands, made upon the surface of attachment on the skull and therefore upon the carrying surfaces of these larger or smaller surfaces of attachment, consist of offering sufficient resistance: to pressure, to tension, to forces causing bending, to forces causing sliding and to forces causing wringing.

α) A compressive force or pressure exercised by a muscle on its own surface of attachment may occur in two forms, one perpendicular to the surface of attachment, the other parallel to this surface. In a very tangentially attached muscle with a musculous attachment to a large area of attachment, one can imagine that during contraction the thickened muscle puts a pressure on the surface of attachment, the pressure acting perpendicularly to the surface of attachment. A pressure parallel to the surface of attachment may occur with a very tangentially attached muscle with a musculous attachment to a large area of attachment, the muscle running along the surface of the skeletal element, for instance parallel to the longitudinal axis of a skeletal bar; one can imagine that the pressure exercised during contraction of the muscle on the skeletal element or bar also influences the area of attachment, leading to its compression (DULLEMEIJER, 1956a, p. 92; 1956b, p. 478).

β) A tensile force is exercised on the skeletal element and its surface of attachment for a muscle in the case of contraction of this muscle. If the axis of the muscle is a continuation of the axis of a cartilaginous spina, the tension of the muscle will have to be very slight, in view of the slight tensile strength of cartilage. If this muscle axis is a continuation of the axis of a bony spina, the tension of the muscle can be of great importance and can be large, owing to the great tensile strength of bone; through this a bony spina can make it possible that great muscular strength is exercised on a small surface. The latter is the case when a small surface of attachment is situated close to the turning-point and, in view of the short arm, the strength will therefore have to be great.

γ) With regard to the resistance to bending we mention the following special cases. In cartilaginous spinae and cristae the resistance to bending is very slight and therefore a transversal attachment to a cartilaginous spina and crista is not readily conceivable; in bony spinae and cristae the resistance is much greater.

The resistance forces against bending can be assumed from the lines which will be perpendicular to the working-lines; this will give a theoretical triangular shape of the bone in a cross section, as is found in cristae (SARKAR, 1960, p. 107).

The bending of spinae and cristae is a process different from that of the bending (flexion) of the surface of the skeletal element carrying the spinae and cristae and also other surfaces of attachment. This bending of the skeletal element will occur in parts of it outside the area of attachment and the resistance against this bending can also be found in parts of the skeletal element not used in the action of the muscle (see DULLEMEIJER, 1956a, p. 83; 1956b, p. 469 on the other wing of the pterygoid in *Vipera berus* (L.)).

δ) Sliding occurs with a tangential, perpendicular power respectively, at the same time with bending. The resistance to sliding will have to be great with a tangential muscle-attachment to a flat, convex or concave surface of muscle-attachment and with a perpendicular attachment to a spina or crista.

ε) Wringing would occur, if a muscle in its action shows an angle between the arm of the moment of the force exercised and the axis of the skeletal part and retains this angle during the time in which the force is exercised.

The resistances mentioned are highly dependent on the structure of the cartilage and the bone from which the carrier of the surface of attachment is built up.

We have to assume that the realizations of the required structures are minimum phenomena; the biological background of these minimum phenomena is not clear as yet (DULLEMEIJER, 1956a, pp. 79/80; 1956b, pp. 465/466).

If one of these resistances are exceeded, irreversible deformation or fracture occurs.

(2) (c) The relation of the form, build, finer structure and position of the projections, deepenings and undulations of the surface of the skull to their function in the service of the spatial arrangement of the muscles and other parts of the head

The projections, deepenings and undulations of the surface of the skull often have an essential function in the spatial arrangement of the muscles and other parts of the head.

All components of the head join together in this head and form a coherent whole. This is the case when all muscles are at rest and also when muscles are in action. When muscles in the head are in action they must be able to functionate without hindrance, although their form or shape and their position may alter. The course of the muscles must be from one place of attachment to the other, whereby as a rule the axis of the muscle must form a straight line.

All this is possible partly because the projections, deepenings and undulations render the surface of attachment of the muscle in size and position independent of the size and position of the carrying surface.

(ii) (3) The functional anatomy of the aponeuroses

(3) (a) Introduction

The aponeuroses show various forms, such as the external groove-shaped aponeurosis, which in shortened form can occur as an external V-shaped aponeurosis; the external tub-shaped aponeurosis, which in shortened form can occur as an external funnel-shaped tendon; the internal plate-shaped aponeurosis, which in shortened form can occur as an internal tendon. They all show a number of variations.

The aponeuroses show a number of functions; we will mention twenty functions in the following pages (see plates 25 & 26). Some aponeuroses show one function, whereas other forms of aponeuroses show more than one function. Some of the functions are limited to certain forms of aponeurosis.

(3) (b) The relation of the form, build, finer structure and position of the aponeuroses to their mechanical function in the muscular action

In the first place it can be established that the form of the aponeuroses in their various forms fits in with their function to offer in their surface an area of attachment to many muscle fibres (first function). An aponeurosis makes it possible for a greater number of muscle fibres to be attached than would be possible on the little surface on the surface of the skull, now occupied by the aponeurosis, in the case of a musculous attachment of muscle fibres.

Examples: (1) On the dorsal part of the crista occipitalis, to which the aponeurosis occipitalis of the musculus depressor mandibulae of *Ardea cinerea* (L.) is attached, there is no place for a musculous attachment (BAS, 1957, p. 484).

(2) In many animals adductor muscles are found running to relatively small areas of attachment on the lower jaw and having an aponeurotic or tendinous attachment (DULLEMEIJER, 1958, p. 84).

It is through this great number of muscle fibres that in the case of an aponeurosis the exercised muscular strength is greater than in the case of a musculous attachment to the small place of attachment of the aponeurosis on the surface of the skull of a much thinner muscle (second function), as is also the case with the musculous attachment of a thin and of a thick muscle (DULLEMEIJER, 1958, p. 82).

With this great muscular strength, the finer structure of the tissue of the aponeuroses will surely fit in, allowing a considerable tensile strength on that surface of attachment. The finer structure is also sure to fit in with the direction of the tensile strength. The size and shape of the area of attachment depends on the form of the aponeurosis.

Examples: (1) The tendinous attachment of one of the parts of the musculus depressor mandibulae in *Vipera berus* (L.) to the caudal face of the lower jaw concentrates a rather strong power on a small spot on the cerebral skull (DULLEMEIJER, 1956a, p. 65; 1956b, p. 451).

This concentration of many muscle fibres on one aponeurosis entails that instead of the many forces exercised according to many different directions because of the large area of musculous attachment, there occurs a concentration of the powers of all these fibres in one direction, *i.e.* that of the aponeurosis, which is moved according to the resultant of the forces exercised by all muscle fibres (DULLEMEIJER, 1952, p. 97) (powers in one direction) (DULLEMEIJER, 1958, p. 76) (third function).

A complicated case is found in the single muscle consisting of a system of a number of feather-shaped units lying in juxtaposition parallel to each other, the internal aponeuroses attached to the two opposite surfaces of attachment forming a system of side-scenes.

An alternation of aponeuroses is found in a muscle when the two places of attachment are close to each other, the volume of the muscle remaining almost the same; over and above this special reason, the shortage of space on the area of attachment and the requirement of mechanical power is a factor for the occurrence of an aponeurosis (SARKAR, 1960, pp. 97, 113).

It must be established that, in a certain volume of muscle with an aponeurosis, there occurs a greater number of muscle fibres than in an equal volume of muscle without aponeuroses, assuming that the relative distances of the muscle fibres are equal. For the muscle fibres are shorter in a muscle with an aponeurosis. From this follow two other functions of an aponeurosis (mentioned below as the fourth and the fifth function).

The enhancement of the strength of a muscle is another function of an aponeurosis (DULLEMEIJER, 1958, p. 80 on the first type of aponeurosis) (fourth function). The strength of a muscle is bound to the number of muscle fibres contracting actively. Comparing further a muscle without aponeuroses to a muscle with aponeuroses of exactly the same content, we assume that the diameters of the muscle fibres are equally large at cross section and that the strength of the muscle fibres is the same; in the muscle with aponeuroses there will be more muscle fibres than in an equally voluminous muscle without aponeuroses (N.B. in the former muscle the muscle fibres are shorter, which, however, is of no influence on the strength). It is thus phrased, that the strength of a muscle is proportional to the "physiologic section", *i.e.* the section touching all muscle fibres transversely. The strength of a muscle will be greater in proportion as there are more muscle fibres in the "physiologic section".

It can also be explained in the following way: as the working-power is proportional to the volume of the muscle and as working-power = lift x power, and as the lift is decreased by the presence of aponeuroses, it follows that the power in muscles with aponeuroses in comparison with muscles of the same volume without aponeuroses must have increased (DULLEMEIJER, 1952, pp. 98, 102).

Examples: (1) The aponeuroses in the musculi adductores maxillae in *Sphaeroides oblongus* (Bloch) fulfill the demand for more power exerting force owing to the particular adaptation to feeding than would be necessary merely for shortening the muscles for closing the upper jaw; in a muscle with alternating aponeuroses the power of the muscle in comparison with those with only one aponeurosis is increased and even more in comparison with muscles without aponeuroses at all; the number of muscle fibres in the muscle is increased whereby the muscle is attached to a minimum area (SARKAR, 1960, pp. 93, 94).

(2) The aponeuroses of the musculus dilatator operculi in *Sphaeroides oblongus* (Bloch) have increased its power so that this muscle has the power to move the operculum lateralwards (SARKAR, 1960, p. 95).

(3) The first part of the musculus adductor internus pterygoideus in *Vipera berus* (L.) shows an area of attachment which is quite unfavourably situated, as the lever to the force is quite small; this unfavourable situation is compensated by the aponeuroses which increase the power (DULLEMEIJER, 1956a, p. 72; 1956b, p. 458).

(4) The considerable force which the musculus adductor mandibulae externus in *Ardea cinerea* (L.) has to exercise, is possible thanks to the aponeurosis (1), while owing to the slanting position of the muscle bundle in which this aponeurosis is situated the percentage lengthening of it in opening the jaw is not very great (BAS, 1957, p. 484).

A strong muscle force is also possible without the presence of aponeuroses. Then we find a great number of muscle fibres in many muscle bundles. This is necessary as there exists an inverse proportion between power and working-distance in every muscle system (DULLEMEIJER, 1956a, pp. 70/71; 1956b, pp. 456/457).

Example: (1) The musculi adductores in *Vipera berus* (L.), running from the cerebral skull to the lower jaw, are divided into many separate muscles, running in quite different directions; there are no aponeuroses in this adductor system with its strong muscle force (DULLEMEIJER, 1956a, pp. 70-71; 1956b, pp. 456-457).

The shortening of the raising-height is another function of an aponeurosis (fifth function). Assuming the degree of shortening of the muscle cells to be the same, which is clear when a muscle fibre can contract to a certain percentage, so in spite of its absolute length, in a muscle with an aponeurosis the raising-height will be slighter than in a muscle without an aponeurosis, for the muscle fibres attached to the aponeurosis are shorter than those in a muscle without aponeurosis (see also DULLEMEIJER, 1959, p. 940).

The functionally necessary raising-height of the muscle, on the other hand, will limit the length of the aponeurosis. The latter is the maximal difference between the distance between the two areas of attachment of the muscle and the functionally necessary length of its contractible muscular part.

Examples: (1) In the musculus retractor vomeris in *Vipera berus* (L.) the moving distance is short and the required power is small, whereas the distance from the olfactorial region to the next fixed point caudal to it is relatively very large; this makes it conceivable that a considerable part of this distance is occupied by a long tendon, running from the vomer to the venter of the muscle in the ventro-caudal corner of the orbita (DULLEMEIJER, 1956a, p. 74; 1956b, p. 460).

(2) The small breadth of the aponeurosis occipitalis of the musculus depressor mandibulae in *Ardea cinerea* (L.) leaves a sufficient length of the muscle fibres to cause the required shortening of the distance between the lower jaw and the cerebral skull (BAS, 1957, p. 484).

(3) In the musculus adductor mandibulae externus et posterior in *Podiceps cristatus* L., which runs from the area of attachment on the squamosum to that of attachment on the lower jaw, and in which the rostral muscle fibres, attached rostrally on the lower jaw, span a longer distance than the caudal muscle fibres, attached caudally on the lower jaw, the necessary contraction asks a different part of the short caudal and of the long rostral muscle fibres; the necessary length of the contractible muscular part leaves an aponeurotically developed remaining length which is very long in the muscle fibres attached rostrally on the lower jaw (BAMS, 1956, p. 101).

(4) In the musculus protractor quadrati et pterygoidei in *Podiceps cristatus* L., which runs from the basis of the neurocranium to the medial surface of the quadratum and the dorsal surface of the pterygoid, and in which some of the muscle fibres span the shortest distance, *i.e.* that between the area of musculous attachment on the caudal surface of the small crista (c.k.) of the pterygoid and the opposite area of attachment of these muscle fibres on the basisphenoid, the necessary contraction thus asks a functionally necessary length of the muscle fibres, being the mentioned shortest distance. In cases of a larger distance occupied by the muscle fibres, the larger distance above this functionally required length of the contractible muscular part is intercepted by the development of aponeurosis (XVII) on the pterygoid (BAMS, 1956, pp. 255-256).

(5) In the musculus adductor mandibulae internus pterygoideus in *Podiceps cristatus* L. we meet a typical example of a muscle requiring for its function only short muscle fibres, but which must bridge a long distance between two bony elements; for this purpose long aponeuroses are necessary. These long aponeuroses are represented in this case by the aponeuroses (XX) and (XXII) on the one side and the aponeuroses (XIX), (XXI), (XXIII) and (XXV) on the other side (BAMS, 1956, pp. 260-261).

In the special case that the angle of attachment of the muscle to the skeletal area of attachment shows very important alterations during the contraction of the muscle, this important alteration in the angle of attachment is possible with an aponeurotic attachment (sixth function).

Examples: (1) In all adductor muscles in *Vipera berus* (L.) except the adductores inserting on the quadratum, the aponeurotic attachment allows a contraction of these muscles in almost every position of the lower jaw, which can turn round an axis parallel in its longitudinal axis and move up- and downwards in all these positions. The adductores to the quadratum in *Vipera berus* (L.) do not show such a structure, which is in accordance with the fact that the quadratum in reference to the lower jaw remains in almost the same parasagittal plane (DULLEMEIJER, 1956a, p. 71; 1956b, p. 457).

In the attachment of a muscle to soft parts an aponeurosis may take part (seventh function). This occurs where muscles end in the skin.

It is not clear what connection there is between the seven functions discussed above and the different forms of the aponeuroses enumerated at the beginning of chapter (I) pp. 19, 22. This is also the case with the finer structure of these aponeuroses, which must also be of great influence on their function.

(3) (c) The relation of the form, build, finer structure and position of the aponeuroses to their function in the service of the spatial arrangement and position of the muscles and other parts in the head

The aponeuroses often perform an important function in the spatial arrangement and position of muscles, of the muscle and muscle fibres attached to these aponeuroses, as well as of other muscles in the neighbourhood and their muscle fibres.

In this first case this concerns the non-straight course of a muscle bundle (eighth function) (DULLEMEIJER, 1958, p. 76). In the special case that between two surfaces of attachment no muscle can go with a rectilinear axis of the muscle, but the muscle bends round something else, an aponeurosis with a given form and build and position can keep the muscle in this bend. Also other cases are conceivable, in which a muscle is given a different direction, being forced by an aponeurosis.

Examples: (1) The aponeurosis (15) in *Sphaeroides oblongus* (Bloch) prevents the musculus $A_1m\beta$ with its curved course round and below the eye and prevents the aponeurosis (14) of the muscle $A_1m\beta$ from pushing the eye from below; this is attained when this aponeurosis (15) has reached a vertical position which results when the musculi $A_1m\beta$ and A_2 are extended (SARKAR, 1960, p. 88).

The aponeuroses make it possible that in size and position the surface of direct attachment is independent of the available space on the carrying surface and the position of the carrying surface.

The aponeuroses make it possible that the available space on a given area of the skeletal surface carries the areas of attachment of all the muscles, one or more, running to that area and besides in the exact mutual position (DULLEMEIJER, 1958, pp. 76, 80 on the second type of aponeurosis) (ninth function). By means of an aponeurosis the muscle can suffice with a smaller area of attachment on the skeleton.

Thus an aponeurosis offers one of the possibilities to bridge places of attachment which are of unequal size (tenth function).

The aponeurosis also offers a possibility to bridge places of attachment which mutually have an unfavourable position (eleventh function) (see DULLEMEIJER, 1958, p. 80); the aponeurosis allows the usual straight course to the muscle fibres (see DULLEMEIJER, 1952, pp. 97, 102; BAS, 1957, p. 484, also on the size and the mutual position of the two places of attachment of the musculus adductor mandibulae externus).

The position of the aponeurosis as surface of attachment is defined, to a considerable extent, by the general direction of the muscle fibres and therefore also by that of the central axis of the muscle.

Considering first the external aponeurosis we see that, at least in contracted position, the muscle fibres will draw an external aponeurosis into a position involving that the muscle fibres approach a tangential position of the muscle fibres on the surface of attachment of the external aponeurosis. The thickness of the muscle fibres, the connecting tissue separating them, as well as the number of layers of muscle fibres attached to the external aponeurosis, determine the angle between the muscle fibres and the surface of the aponeurosis, and so the position of the external aponeurosis in the contracted condition of the muscle. Usually a muscle, the fibres of which are attached to an external aponeurosis, will not be thick. Another position of an external aponeurosis is possible, if it is part of a complicated aponeurosis system, showing an ossified basic part (BURGGRAAF & FUCHS, 1954, p. 289; BURGGRAAF, 1954, pp. 299, 303) or if, on its free edge, it shows the character of an internal aponeurosis and consequently takes a different position in regard to the basally attached muscle fibres.

Considering now the internal aponeurosis, we see that, in the contracted condition of the muscle fibres, it will be drawn into such a position, that the internal aponeurosis will divide the angle between opposite muscle fibres in two equal parts, if these muscle fibres contract simultaneously and equally strongly. The said condition reckons with the fact that the muscle fibres implanted on an internal aponeurosis can form any small but also large angle with it. As a result the direction of the power exercised by the muscle fibres on an aponeurosis is always entirely in the plane of the aponeurosis (see also DULLEMEIJER, 1952, p. 96).

Not only with respect to the space for attachment of muscles, but also with respect to the occupation by the bodies of the muscles of the space, lying between skeletal parts, thus of adjacent muscles, the aponeuroses play a role (twelfth and thirteenth function). In the first place the aponeuroses make it possible that branches of a muscle or that adjacent muscles show cross sections of comparable value that do not lie in one and the same cross section of the entire muscular complex (twelfth function).

In the second place aponeuroses make it possible that such a space, even one of an extremely irregular shape, can be filled by branches of a muscle or by adjacent muscles, owing to a partition of this space in smaller parts showing a more simple or regular stereometric shape (VAN VENDELOO, 1953, figs 8, 11b & c) (thirteenth function).

In a special case a right and a left muscle are connected in the median plane not by a skeletal element but by an aponeurosis lying in the median plane and connecting these two muscles in the median plane (fourteenth function).

A separate group of functions of aponeuroses occur in the case of so-called "intermediate aponeuroses", *i.e.* those aponeuroses which lie intermediate between two or more muscular parts of a composite or combined muscle. Among the functions of these aponeuroses some principal differences occur, which allow us to distinguish a number of functions (fifteenth, sixteenth, seventeenth, eighteenth, nineteenth and twentieth function).

In a few special cases an "intermediate aponeurosis" is found in a muscle which bridges too great a distance between two remote points of attachment, which distance is too great for one single muscle cell (BAS, 1957, p. 484) (fifteenth function).

Examples: (1) The tendon connecting the rostral with the caudal venter in the musculus biventer cervicis in *Phasianus colchicus* L. and in *Perdix perdix* L. must be seen as a way of transition of the force in order to bridge a greater distance than a bundle of parallel muscle fibres could do (DEN BOER, 1953, p. 471).

The functionally necessary length of the contractible part of the muscle is, in a number of cases, only a part of the entire distance between the two areas of attachment; this difference in length is filled up by an aponeurosis.

Examples: (1) In the musculus adductor mandibulae internus pterygoideus in *Crotalus viridis* the length of the aponeurosis is half the length of the entire muscle; in its antagonist, the musculus protractor pterygoidei which as an antagonist must have a comparable function, shows a length of the muscle part, however, which is about twice longer than or twice as long as that (both relations are given) of the musculus protractor pterygoidei which due to the presence of some aponeuroses, necessitated by the restricted surface of both areas of attachment (DULLEMEIJER, 1958, p. 83).

In a few special cases an "intermediate aponeurosis' is found in a muscle which runs through a narrow canal, so narrow, that it makes the course of the muscle as one whole before and inside and behind this canal impossible; the "intermediate aponeurosis" connects the two muscular parts (sixteenth function).

In a few special cases an "intermediate aponeurosis" is found between two muscle bundles showing a different course, the angle between the bundles being less than 180°; the "intermediate aponeurosis" makes a cracked course of the muscle possible (seventeenth function).

In a few special cases an „intermediate aponeurosis" occurs in the shape of a muscle with two ends attached to two skeletal parts and with an intermediate connection with a third skeletal part through an "intermediate aponeurosis" (eighteenth function).

Examples: (1) The musculus digastricus in *Ondatra zibethica* (L.) (Mammalia) is attached to the lower jaw and to the processus paroccipitalis and by means of an intermediary aponeurosis is also attached to the os hyoideum (VAN VENDELOO, 1953, pp. 268-270).

In a few special cases an "intermediate aponeurosis" has the shape of a complicated branched, forked plate in which a number of muscle bundles running in different directions are implanted (nineteenth function). In a certain respect it resembles a toy supple-jack; the body and the proximal parts of the arms, legs and the two strings resembling the complicated branched, forked aponeurotic plate, the distal parts of the arms, legs and the two strings representing the muscles.

In special cases intermediate aponeuroses may also have the function of permitting a separate contraction of the different branches of the muscle (DULLEMEIJER, 1956a, p. 66; 1956b, p. 452) (twentieth function).

(ii) (4) The functional anatomy of the muscles

Starting from the form, build, finer structure and position of a given muscle, a close relation with the muscular action is distinct and will be discussed in the following pages. This is not the case with the spatial arrangement of the muscles.

As regards the external forms and the build of the muscles, the muscles show various external forms and also vary in their build, especially in regard to the position of the aponeuroses. On the strength of the knowledge of form, build and also of finer structure, as we will see, a connection can be sought with the roughly outlined or only supposed function.

An element in the external form of the muscle is its size; this too is correlated to the function of the muscle. We only mention that a long muscle means a high raising-height.

Examples: (1) The musculus adductor mandibulae externus in *Phalacrocorax* and in *Ardea*, which both have big preys, reaches the dorsal median of the skull (BAS, 1957, p. 485).

As to the external form of the muscles in a proper sense we mention here the following conditions (a survey of a number of these types of muscles, based on the relative size of both places of musculous attachment of a muscle is given by DEN BOER, 1953, pp. 470-472).

1) The single, non-branched, non-forked muscle is a solid, stereometric body, the cross section of which is of the same size and the same form in different places, whether of a circle (with a cylinder), or of an ellipse, *etc.*

The muscle fibres will run parallel to each other. The size of the two surfaces of attachment and the angle of implanting of the muscle fibres on the two surfaces of attachment depend on the position of the surfaces of attachment in respect of the longitudinal axis of the stereometric body and on the shape of the surface of attachment.

2) The single, non-branched, non-forked muscle is a solid, stereometric body, the cross section of which varies in size in different places, but has the same form, whether a circle (with a cone), or an oval, *etc.* The muscle fibres will diverge or run parallel, at least the central muscle fibres (in the presence of an external funnel-shaped tendon). One surface of attachment on the skull is small in proportion to the other.

3) The muscle is of a different and much more complex structure; the muscle may consist of a system of a number of feather-shaped units lying in juxtaposition parallel to each other, the muscle fibres forming interrupted zigzag lines, the internal aponeuroses forming a system of side-scenes; the muscle may consist of a number of layers in which the muscle fibres show quite different courses and cross each other; the muscle may consist of parts of different thickness, which gives an irregular outline of the muscle at the surface of attachment and thus also of the shape of the muscle in cross section (see COOL, 1952, p. 634); the muscle may be a branched, forked muscle and the muscle may be a composite or combined muscle, interrupted by a piece of non-muscular tissue or interrupted by a number of myosepta (see p. 66). All these types of muscles show many variations.

As to the finer structure of the muscle, especially the relative positions of the muscle fibres, we have already discussed (see p. 69) the relative positions of the muscle fibres in connection with the classes of muscles, distinguished on account of their form and build.

The relative positions of the muscle fibres are also connected with the effects of the contraction of the muscle on the position of the two points or areas of muscular attachment.

The angle of attachment of the muscle fibres in regard to the surface of direct attachment (cartilage, bone, aponeurosis, or tendon), in the second place the parallel or non-parallel position of the surfaces carrying the places of attachment of the muscles and in the third place the opposite or non-opposite position of the surfaces carrying the places of attachment of the muscles, are determinative for the function of the muscle and for the effects of the contraction of the muscle on the position of the moving skeletal part in regard to the non-moving skeletal part.

Generally we may say that every muscle makes the points to which it is attached approach to each other. As for the muscle as a whole, this assumption may give complications if the muscle is a composite one. The balance between the tensions of different muscles makes it almost impossible to determine the share of a muscle in the contraction during a certain movement (DULLEMEIJER, 1956a, pp. 64, 66; 1956b, pp. 450, 452). On the other hand, the fact that most muscles can contract about 50% to 60% of their length at rest, if they have to maintain a tension above a certain level, cannot be applied for calculating the force in a complicated muscle system, as it is not known which contribution a particular muscle delivers to the resultant of the forces exerted by different muscles in contraction during a certain movement, and as it is not known which part of a muscle is active during a certain function, and as experiments involving activation of an individual muscle in the intact organism cannot solve the problem (SARKAR, 1960, p. 89).

With regard to the position of the moving skeletal part and the non-moving skeletal part, we can distinguish four cases.

a) In the case of one surface of attachment moving parallel to itself and parallel to the other surface of attachment, the muscle fibres may show a parallel course or they may diverge or converge. If the muscle fibres run parallel to each other, this course will not be altered in contraction. If the muscle fibres diverge or converge, the course will not be altered either. The angle of attachment with the two surfaces of attachment, however, will get another value. If the principle of MOLLIER (see p. 194) is to remain valid, the shifting will have to be bound to certain limits.

b) In the case of one surface of attachment rotating in respect of the other surface of attachment and the point or the axis of rotation lying within one of these surfaces of attachment, there is a difference in the course of the muscle fibres depending on the relative size of the surfaces of attachment. If one surface of attachment is small in respect of the other, the muscle fibres will not contract simultaneously, or contract equally much. These muscle fibres can form a conic muscle bundle or a fan-shaped one, or they can form layers of muscle fibres, in which the muscle fibres go in different directions. If one surface of attachment is as large as the other, then, too, the muscle fibres will not contract simultaneously or contract equally much. The muscle fibres will run parallel to each other, or they can form layers of muscles fibres, which go in different directions. As differently directed muscle fibres in a muscle do not contract simultaneously, but in consecutive groups are dependent on the successive positions reached by the skeletal elements during the movement, we must not consider the whole of the muscle in determining its power, but the effective muscle fibres at any given moment. Of course this working-pattern has its consequence for the structure of the muscle and of the bony parts to which the muscle is attached (DULLEMEIJER, 1952, p. 96).

c) In the case of one surface of attachment rotating in respect of the other surface of attachment and the point or the axis of rotation lying outside these two surfaces of attachment, there are many differences in the course of the muscle fibres. It now depends (a) on the distance from the place of attachment of the muscle fibres to the point or the axis of rotation, (b) on the breadth of the two surfaces of attachment in the surface of shifting, (c) on the question how the finer structure of the muscle is (parallel muscle fibres, fan-shaped or conic, whether or not it consists of layers of muscle fibres in which the muscle fibres go in different directions), how the angle of incidence of the muscle fibre changes in respect of the surface of attachment in continued motion of the moving surface and how the principle of MOLLIER (see p. 194) is fulfilled with it.

d) In the case of one surface of attachment rotating in respect of the other surface of attachment and the point or the axis of rotation lying not only outside these two surfaces of attachment, but also shifting during this rotation, there are appropriate courses of the muscle fibres.

Examples: (1) The muscles attached at one end to the cerebral skull and at the other end to the chain of bony elements, constituted by the supratemporale, by the old upper jaw (quadratum, pterygoid, palatinum) and by the maxillare, rotate this chain of bony elements in the way mentioned, in *Vipera berus* (L.) (DULLEMEIJER, 1956a, pp. 54 *sq.*; 1956b, pp. 440 *sq.*). With the exception of the two terminal bony elements (the supratemporale and the maxillare) the intermediate skeletal elements show a complicated way of rotation which can be analysed in: a rotation round one axis, a displacement parallel to itself and a rotation round another axis. The two terminal elements of the chain (the supratemporale and the maxillare) do not turn round an axis, but turn round a fixed point resulting in a movement in two directions. Such a movement is exerted by the musculus protractor pterygoidei, which moves the distal area of attachment in the direction of the proximal area of attachment and also more dorsalwards, the latter owing to a turning of the supratemporale. Such a movement is also exerted by the musculus levator pterygoidei, which even with a slight contraction moves the area of attachment in the direction of the proximal area of attachment and also more rostralwards, the latter owing to a turning of the supratemporale, the quadratum, the old upper jaw and the maxillare.

(2) The musculi adductores running from the cerebral skull to the lower jaw (and also from the upper jaw to the lower jaw; the musculus depressor runs from the quadratum to the lower jaw) in *Vipera berus* (L.) (DULLEMEIJER, 1956a, p. 63; 1956b, p. 449) may close the lower jaw as well as displace the jaw joint, which is due to the fact that the skeletal connection of the jaw joint to the cerebral skull is movable.

(ii) (5) The functional anatomy of bigger parts of the surface of the skull

The surface of the separate projections, the separate deepenings and the separate undulations of the cranial surface, treated separately in the above sections, form one functional component of lower rank on one hand, but on the other they form an element of a more comprising part of the skull, which should be examined as much. Very seldom a separate projection, *etc.* is an entirely separate and independent functional element, not being included functionally as a member in a more comprising part.

The more comprising part of the skull, containing one or more projections, one or more deepenings, one or more undulations of the cranial surface, can be the entire surface of a skeletal element or of a functional skull-component, *etc.*

A skeletal element carrying these surfaces presents volume and shape. In considering these last-mentioned features too, we enter quite different fields, such as was done by DULLEMEIJER (1956a, 1956b, 1957, 1958, 1959) concerning the skull.

This more comprising skull element or functional skull-component or skull surface can fulfil a number of "functions", so more than the only function of attachment of a muscle.

"Function" is used in various senses, depending on the various levels into which the functions are divided. Function means a partial function as well as a total function and all the levels in between.

As soon as an element shows more than one function, belonging to different upper functions or being different partial functions of one and the same upper function, we have four theoretical possibilities (VAN DER KLAAUW, 1948a, pp. 39/40; DULLEMEIJER, 1956a, pp. 79, 92, 105/106, 107/108; 1956b, pp. 465, 478, 491/492, 493/494; 1959, p. 974).

1. The various functions are performed by morphological elements either on one single skull element or on a bigger part of the skull as a whole. In both cases it is performed either on the surface or on the surface together with lower skeletal layers. In these cases the said morphological elements are situated beside or under each other, the functions being separately realized; in performing their function these elements have nothing to do with each other (principle of pocket-knife with little knives, corkscrew, *etc.*). We mention: two or more entirely separated areas of attachment for two or more different muscles on one and the same skeletal element; a small surface of musculous attachment and on the same skull surface a groove for a blood-vessel; a perpendicularly projecting relief-element for the attachment of a muscle and the layer of the cranial wall beneath it to conduct the pressure exercised by the resistance of the surroundings, as occurs with swimmers and diggers.

2. The various functions are performed by the same morphological elements, an integration or a compromise being out of the question. We mention: a skeletal surface of musculous attachment is at the same time the skeletal covering of a semi-circular canal, such as is the case with Squaliformes; a surface for the attachment of a muscle together with the skeletal tissue beneath it offers resistance to the tensile power of a muscle and also conducts the chewing-pressure; a surface for the attachment of a muscle together with the skeletal tissue beneath it offers resistance to the tensile power of a muscle and also to bending, as is the case with the suspensorium of Pisces; the construction for swallowing the prey in *Vipera berus* (L.) is the same as that for poisoning the prey by a poison injection (DULLEMEIJER, 1956a, pp. 54, 65, 68-69, 106; 1956b, pp. 440, 451, 454-455, 492).

3. The various functions are performed by the same morphological elements, which goes along with an integration in the form, build and finer structure (DULLEMEIJER, 1956a, p. 106; 1956b, p. 492). We mention: the middle part of the pterygoid in *Vipera berus* (L.); the part of the lower jaw rostral to the jaw joint in *Vipera berus* (L.).

4. The various functions are performed by the same morphological elements, which goes along with a compromise in the functions as well as in the form, build and finer structure, as the demands made upon the skeleton are contrary. To get an insight into this situation we have for each separate function to state the optimal function as found in related systematic groups and we have to establish the optimal situation of the form, build and finer structure, which is required by this separate function, in that optimal function in the species studied. With the surfaces of attachment for muscles, whether or not through the medium of an aponeurosis, we may expect a compromising situation in the course and position of those cranial surfaces, if they are mainly or entirely determined by the other functions presented by the cranial wall in question and which latter functions are decisive for the position *etc.* of this cranial wall. We mention: the position of the surfaces for the attachment of muscles on a very thin cranial wall covering the cranial cavity for the brain; the position of the surfaces for the attachment of muscles on a tender lower jaw, *etc.* In order to attain its optimal or necessary effect the muscle withdraws from this compromise regarding the attachment of muscles by developing cristae and especially spinae, or by developing another muscle performing the same function.

In a number of cases it is not distinct which of these four theoretical possibilities is present.

With the cervical muscles in *Vipera berus* (L.) *e.g.* it is difficult to prove a strict relation between form and function, whether on the ground of an integration or a compromise or not, because of the fact that these muscles show two different functions (bending of the head and the cervical column and the rostralward movement of the cerebral skull) (DULLEMEIJER, 1956a, p. 73; 1956b, p. 459).

(ii) (6) The functional anatomy of complicated muscles or of muscle systems with a system of aponeuroses

The simply built muscles, with at each end an aponeurosis at most, form only part of the cases occurring in Vertebrates.

Beside it also occur complicated muscles or even muscle systems, which may possess an extensive system of aponeuroses (see pp. 28 and 66). The function of such muscles is certainly rarely known. We do not know how the parts function after each other in time and in what degree they contract in different cases, and what force they exert with it. The co-ordination of muscular actions in a complicated muscle and in a complicated system of muscles deserves a thorough investigation, also as to the force they exert and in what direction.

In all the cases discussed only adult conditions of recent animals were dealt with. Very little is known about the functional anatomy of head muscles in ontogenetic stages; yet it must be highly important, not only in connection with the requirements of life of every stage, but also in connection with the transition from one stage into the next. Speculation still plays a great part here. It is the larval stages that are the best-known.

On the functional anatomy of head muscles in fossils we can naturally only make speculative remarks, so that there is nothing to report on the phylogeny of form and function of head muscles.

(IV) (iii) *The relation form-function in a consideration putting the function primarily*

(iii) (1) Introduction

Here the starting-point is the examined function. This will preferably have to be a direct function-determination obtained by observation and supplemented by an experiment with quantitative determinations (for some historical facts see DULLEMEIJER, 1957).

It is then considered in what way and to what degree this function fits in with the form of the morphological element; the build and the finer structure as well as the position come up for discussion in so far as they are rougly known, or have been established, or are presumed.

"Function" is used in different senses.

"Function" can be used in the sense of proper function; in the case of a muscle this means an active contraction. If this does not occur one may speak of "functionless muscles".

On the problem of the possibility of forms without function in general we may remark that it is possible that the function is unknown (JEUKEN, 1958, p. 40) or is entirely different from the function in allied species, *etc.* (JEUKEN, 1958, p. 40). This "absence of a function" can of course be an observational mistake (BAS, 1957, p. 484).

As to this problem in muscles CORDS (1922) has given a summary and a discussion on the many muscles which in literature are called functionless, discussing the different meanings of this term "functionless" and discussing the causes of the development of these states of being functionless in muscles. "Functionless" in the common sense are called those muscles which at both ends are attached to immovably connected skeletal elements or skeletal parts; "functionless" are called those muscles which during contraction of the muscle fibres hardly show a shortening of the entire length of the muscle. Among the causes of functionless muscles are mentioned: an active muscle function in a phylogenetically older stage; a development of the muscle over an enlarged area of attachment in a phylogenetically older stage which has not atrophied and which has not been changed into connective tissue bands, into ligaments or into tendines nor into membranes or into aponeuroses. Maintenance of muscle fibres in functionless muscles is found in the cases of absence of pressure on the muscle and in the case the innervation is not lost, which can occur in the case of muscle parts belonging to bigger muscular complexes.

There are various levels of functions. There is the "proper function" ("Eigenfunktion", DRIESCH) of a cell, of a tissue, of an organ, *etc.* Each of these functions also shows a "harmonic function" ("harmonische Funktion", DRIESCH) for the higher totality, such as the tissue, the organ, the organism as a whole, also the colony, the biocoenose (JEUKEN, 1958, pp. 36, 38).

The idea of biological function is a dynamic one (JEUKEN, 1958, p. 32). We may divide the functions into statical or mechanical functions and into dynamical or active functions (JEUKEN, 1958, pp. 32-33).

The concept of function can be used in a "vertical" line as activity, as causal relation and as teleological relation. Activity can be distinguished in actual active functions (the action is seen here as the performance of a function) and in potential active functions. — The concept of function can be used in a "horizontal" line, if we distinguish the diverse kinds of functions, as mechanical, chemical, physical, ethological, ecological function (JEUKEN, 1958, pp. 38-40).

We may give the following definition of a biological function according to JEUKEN (1958, p. 41): a biological function is a property of a definite part of the total organism, marked by a certain form or structure, which property is actual or potential activity itself or directly related to activity, and by which the development and the maintenance of the organism as a whole is enable to proceed in a harmonious way.

We have to distinguish on the one hand a function related to the totality of the organism, a "Ganzheitsfunktion" (DRIESCH) or totality-function, and on the other hand all other functions as proper functions or "Eigenfunktion" (DRIESCH). These proper functions are related to small and to much embracing partial functions. Among these functions we may distinguish major top functions, such as feeding, and minor top functions, such as for instance food intake, food retention, killing a prey, breaking up the food, *etc.*, and in the third place still smaller partial functions, such as sucking or chewing.

We find that in every animal species a co-ordinated system of muscles plays a part peculiar to the species, in the totality-functions as well as in the major top functions, the minor top functions and as also in the smaller partial functions. On the ground of our insight in this co-ordination of the smallest partial functions, *e.g.* those of the many separate muscless, united in a system of muscles, we shall have to recognize the relation of form and function in the complexities of a gradually rising level (DULLEMEIJER, 1956a, p. 60; 1956b, p. 446).

In the case of a subordinate partial function or small process or part of a process, exercised by simple muscles and by parts of muscles separately, knowing the function of such muscles by direct examination in a number of cases, an indirect function-determination can be approached by a consideration based on analogy, from the length of the muscle, the "physiologic cross-section" of the muscle, from the development and the position of the aponeurosis and those of the projections, deepenings and undulations of the surface of the skull.

In the case of partial functions of a higher level, such as a more comprising function or greater process, an indirect function-determination is not well possible. There are a number of possibilities. We may think of a complicated contraction as well as of the function of muscles working co-ordinately with each other, whether or not belonging to a construction in the sense of BÖKER (1935, pp. 7-8, 8; 1936, pp. 29-30; 1937, pp. vi-vii). According to BÖKER the conception of a construction may be formulated as follows: A construction consists of components, the combined action of which makes the practice of a certain expression of life and the condition of being adapted to certain environmental factors possible; every anatomical construction is specialized for a corresponding expression of life and corresponding environmental conditions (see VAN DER KLAAUW, 1948a, p. 69).

Finally we may think of still more comprising chief functions or minor top functions, even of a major top function.

We will deal with the smaller functions effected by a simple muscle and with the more comprising, complicated functions separately.

(iii) (2) The functional anatomy of the smaller function, effected by a simple muscle

If we want to proceed on the function of a muscle, also of a simple muscle, and if we want to have an exact quantitative knowledge of it, the following would have to be known (DULLEMEIJER, 1957, pp. 6-7):

a) the strength-diagram would have to be known with the absolute scope of the forces exercised by the muscles, and of the internal tensions evoked by the former;

b) the average and the maximal forces exercised by the muscles and by the aponeuroses would have to be known.

It may be considered in what way and to what degree the form, *etc.* of the morphological element fits in with the exactly known strength-diagram, the average and the maximal scope of the external forces and the internal tensions. At most this leads to a qualitative insight, based on a few or a number of cases for which the above data are accurately known

We assume that of this morphological element we do not have any exact data about the properties of the cartilage and the bone, and that we do not know the nature of the construction of this morphological element, which would be essential for a clear understanding of the changes in form and of the tensions, so that we are not sure whether we may take the skeletal element as a minimum realization in mechanical respect, or whether additional functions do not make this probable.

What was summed up about the three main types of muscles (p. 212) in connection with the parallel shifting or the rotation of the shifted surface is also of great importance for the functional anatomy of these simple muscles.

(iii) (3) The functional anatomy of the more comprising function, effected by a system of muscles or a more complicated muscle

In thinking of a more comprising function we must reckon with a combination of partial functions or with a more complicated function, such as a minor top function or a major top function, *etc.* They may be effected by a more complicated muscle or by a system of muscles, belonging to various classes of cases in functional-anatomical respect.

In the first place we think of muscles the fibres of which contract after each other, which may always be the case, but very clearly with muscles of which the fibres lie in different layers contracting after each other.

Examples: (1) The high differentiation of the mandibular portion of the musculus adductor mandibulae in *Sphaeroides oblongus* (Bloch) does not find its functional basis in carrying out different kinds of movements — the movement of the lower jaw is restricted to a vertical movement of the jaws and no movement in any other direction occurs or is a necessity for biting and crushing purposes during feeding — but the differentiated parts of the musculus adductor mandibulae may act at different phases in the movement of the lower jaw; in the process of closing the mouth cavity the muscle A_3 with its aponeurosis (*5*) will contract first and will pull up the lower jaw and thus will make the positions of the aponeuroses (2) and (3) of muscles A_1 and A_2 suitable for work; the last phase is the rigid closing of the lower jaw by contraction of the muscle A_1 (Sarkar, 1960, pp. 89-91). The different muscle fibres in the different parts of the adductor mandibulae muscle, especially also of musculus A_3 and A_2, show such a direction that these different parts of the muscle are in favourable positions in different phases of the opening of the lower jaw. This requirement may have led to the differentiation of the adductor muscles (Sarkar, 1960, p. 93).

(2) The fact that the musculus adductor in *Vipera berus* (L.) running from the cerebral skull to the lower jaw, is divided into many separate muscles, running in quite different directions, — a rather curious situation, almost realized in snakes only —, can be explained by the fact of the wide opening of the mouth. The lower jaw can move over a large angle and owing to these many separate muscles in almost every position of the lower jaw a muscle is found that runs perpendicularly to the longitudinal axis of the lower jaw (Dullemeijer, 1956a, pp. 70, 71; 1956b, pp. 456, 457). The wide opening of the mouth is related to the intake of a big prey. This requires a far caudally situated soft angle of the mouth (corner of the soft margin of the mouth slit) and in consequence of this the attachment of the muscles to the jaw is also far caudal. The combination of the wide range of

movement of the lower jaw and this caudal situation of the muscles accounts for the curious course, parallel to the lower jaw, of the muscles in rest, as well as the lack of internal aponeuroses. Both these features occur in long muscles which can contract over a long distance (DULLEMEIJER, 1956a, pp. 70, 71; 1956b, pp. 456, 457).

In the second place we think of muscles with a complicated system of aponeuroses.

In the third place we think of a combined or composite muscle, which is interrupted by a piece of non-muscular tissue which separates two parts of one muscle or connects two or more muscles (see p. 66).

In the fourth place we think of a system of two or more separate muscles, which may even belong to various classes of cases in functional anatomic respect.

Examples: (1) A number of separate muscles render a service in the movement of opening and widening the mouth cavity and closing and narrowing it again during feeding in *Sphaeroides oblongus* (Bloch) (SARKAR, 1960, pp. 80 *sq.*, 91 *sq.*). Necessary general remarks (see also the examples in (3) *Vipera*) we have to make in advance are: the muscles and the skeletal upper and lower jaw, *etc.* will be discussed only in so far as they serve the top function of feeding, whereas we will discuss later, how similar structures for a certain part carry out the function of respiration (see also *l.c.*, p. 87). We add, that in general we may say that the realization of feeding depends on the way of feeding, on the kind of food, on the way of killing, of smashing and of swallowing the prey. The detailed structure of the apparatus for the different minor functions depends on the requirements of these functions, on the influence of the members of the apparatus on each other, and on the influence of other functional components and other local influences (see the example in No. 3). — Remarks that have to be made on the skeleton involved are the following (SARKAR, 1960, pp. 80 *sq.*). The apparatus for feeding consists of a number of skeletal elements as are summed up in the following notes on the movement of skeletal elements during the opening of the mouth and the widening of the mouth cavity for feeding: the lower jaw with its anterior end is pulled backwards and downwards, only in the vertical plane and no lateral movement can be observed, neither in the lower jaw nor in the upper jaw; the movement of the interoperculum plays a role in the depression of the lower jaw by pulling its posterior end upwards owing to the position of the interoperculum and its connection with the operculum and the skeletal lower jaw; simultaneously with the described movement of the lower jaw the upper jaw is pulled forwards and upwards; there is no separate movement of each half of the praemaxillare nor of that of the maxillare nor of that of the old upper jaw; there is a slight upward lifting of the cerebral skull from the axis of the vertebral column; a lowering of the hyoid bar in the caudal part of the pharyngo-oral cavity takes place when the shoulder girdle is pulled downwards and backwards, a movement which is transmitted to the branchial apparatus; the branchial arches and the ventral element of the hyoid bars are also pulled backwards and downwards; the hyoid bar shows a limited rotatory movement as there is no movement of the rostral part of the suspensorium; there is not much bending at the connecting regions of the small hypohyalia, epihyalia and interhyalia to the ceratohyale; there is some lateral extension of the caudal half of the hyoid bar and the shoulder girdle, simultaneously with the lateral movement of the caudal part of the suspensorium. — During the movement of closing and narrowing the mouth cavity for feeding we find movements of the skeletal elements opposite to those described for the opening and widening of the mouth cavity: the lower jaw is pulled forwards and upwards, the interoperculum is moved in the opposite direction and with it operculum and lower jaw, the upper jaw is pulled backwards and downwards, the slight turning of the cerebral skull is neutralized, the hyoid is pulled forwards back to its position of rest, the shoulder girdle, branchial arches and caudal part of the suspensorium are brought back to their position of rest. — The separate muscles functioning in the movement of opening and widening the mouth cavity for feeding are the following: the first way of depressing the lower jaw *i.e.* by pulling the anterior end of the skeletal lower jaw downwards and backwards, takes place by a system of muscles and bones of the ventral side of the body and head; it takes place from the caudal direction by the contraction of the sternohyoid muscle (from cleithrum to hyoid bar) through and together with that of an expanded position of the geniohyoid muscle (from ceratohyale to skeletal lower jaw). The second way of depressing the lower jaw is by pulling the posterior end of the skeletal lower jaw upwards through the mediation of the interoperculum; a group of ventral muscles assisted by the movements of the shoulder girdle may pull the lower jaw downwards. In relation to the position of the geniohyoid muscle and the lines of force, as well as in relation to the position of the interoperculum, the force is exerted below the fulcrum (the articulation between the lower jaw and the quadratum) (there is a negative moment about the fulcrum). When the lower jaw drops quickly the posterior end of the maxillare is carried forwards by the thick connective tissue band between lower jaw and maxillare with praemaxillare. The simultaneous opening of the upper jaw may be achieved partly by the connective tissue band joining the upper and lower jaws, partly by the lifting of the cranium. Although some portions of the supracranial muscles, *etc.* may suggest the lifting up of the cranium, still, in practice, these muscles can have little effect in pulling up the upper jaw and in forming a wide mouth cavity. The vertical expansion of the pharyngo-oral cavity is mainly achieved by the contraction of the ventral muscles along with the caudal turning of the shoulder girdle (the shoulder girdle is pulled downwards and backwards); this movement of the shoulder girdle is transmitted to the branchial apparatus and, at the same time, by the contraction of the sternohyoid muscle and the branchial muscles; the branchial arches and the ventral part of the hyoid bars are also pulled backwards and downwards. All these contractions of the muscles and movements of the bones result in the vertical extension of the pharyngo-oral cavity. This movement can be achieved by the contraction of the big muscles of the body and by the ventral muscles assisted by the sternohyoid muscles. It is possible that the small musculus levator arcus palatini helps to lift laterally the caudal part of the suspensorium (hyomandibula, symplecticum, a part of the praeoperculum). — The separate muscles functioning in the movement of closing and narrowing the mouth cavity for feeding are the following: the contraction of the musculus adductor mandibulae will pull the lower jaw upwards and forwards; the contraction of the musculus adductor maxillae will pull the upper jaw backwards and downwards; the musculus $A_1\alpha$ will actively help in drawing back the upper jaw; the genohyoid muscle will pull the hyoid forwards back to its position of rest. — We have to add two special notes. An accessory function in the closing of the mouth is the function of biting the prey or of breaking the prey into small pieces or of crushing the prey within the mouth (see Sarkar, 1960, pp. 87, 94). A second extra function is the rigid closing of the upper jaw, to which the musculus $A_1m\alpha$ gives accessory help (see also Sarkar, 1960, pp. 91, 93-94).

(2) A number of separate muscles render a service in the movement of opening and widening the mouth cavity and closing and narrowing it again during respiration in *Sphaeroides oblongus* (Bloch) (Sarkar, 1960, pp. 80 *sq.*, 91 *sq.*, 103, 107). Necessary general remarks (we refer also to those in the foregoing paragraph) we have to make in advance are: the muscles and the skeletal upper and lower jaw, *etc.* will be discussed only in so far as they serve the function of respiration (we have discussed in the foregoing paragraph how similar structures for a certain part carry out the function of feeding; see also Sarkar, 1960, p. 87). — Remarks that have to be made on the skeleton and the muscles involved are the following. The apparatus for respiration for a certain part is similar to that for feeding and contains part of the elements of the apparatus for feeding. On the other hand the apparatus for respiration also contains the movable caudal part of the

suspensorium, articulating with the cerebral skull and possessing an articulation between the quadratum and the praeoperculum. Thus we can confine our notes to some additional ones. — In a complete respiratory cycle the first movement is the contraction of the musculus dilatator operculi which lifts the operculum slightly laterally, and in this position the contraction of the musculus levator operculi (running from the caudal part of the operculum to the anterior arm of the temporal process, which is both caudal and dorsal to the operculum) tends to lift the operculum caudo-dorsally (this lateral movement of the operculum was observed to be much smaller in comparison to its caudo-dorsal movement); this movement of the operculum is transferred to the interoperculum and the lower jaw, the caudal part of which is pulled upwards. The lateral and the caudo-dorsal movement of the operculum are synchronised with the lowering of the rostral part of the hyoid bar and a slight depression of the lower jaw respectively (during respiration the lower jaw is only slightly depressed; the lower jaw is pulled less far downwards and backwards during respiration than during feeding). This slight lowering of the lower jaw which is simultaneous with the movements of the operculum is probably done without the active co-operation of the geniohyoid muscle or the sternohyoid muscle. — In the second phase of the respiratory cycle the lower jaw is pulled upwards, drawing the operculum forwards; the hyoid bar is lifted up and the caudal half of the suspensorium is expanded laterally, followed by the return of the operculum to its normal position. Contraction of the anterior segments of the body does not play a role in movements concerned with respiration. The adductor mandibulae muscles, especially muscle A_1, raises the lower jaw when it is slightly depressed during respiration and thus can act as an antagonist to the musculus levator operculi, whereas the contraction of the musculus adductor operculi brings the operculum back to the normal position. The musculus adductor operculi probably works as an antagonist to the musculus dilatator operculi (pp. 94, 107). — As we have seen there is a considerable movement of the opercula and also of the caudal and the mid-ventral parts of the suspensorium, but an immovability of the rostral part of the suspensorium, which will automatically limit the expansion of the pharyngo-oral cavity in *Sphaeroides oblongus* (Bloch), which is different from many other fishes.

(3) A number of separate muscles render a servive in the movement of the bony upper jaw and in the turning of the maxillare in *Vipera berus* (L.) (Dullemeijer, 1956a, 1956b). Before discussing the system of separate muscles we have to start with some general remarks on the system in general and on the skeletal parts involved. — General remarks that have to be made are the following (Dullemeijer, 1956a, pp. 57, 58, 59, 63; 1956b, pp. 443, 444, 445, 449). The muscles, the bony old upper jaw and the maxillare, and the lower jaw, serve the two minor top functions of injection and of swallowing, which together belong to the major top function of feeding (one of the seven major top functions, realized in the head of *Vipera berus* (L.)). For a better understanding of the system of muscles and skeletal parts belonging to the top functions mentioned, it should be kept in mind, that the realization of feeding in general depends on the way of feeding and on the kind of food; in snakes it depends on the way of killing and of swallowing the enormous prey. The detailed structure of the apparatus for poisoning and for swallowing depends on the requirements of the function, on the influence of the members of the apparatus on each other, and on the influence of other functional components and other local influences. — Remarks on the skeleton involved that have to be made are the following (Dullemeijer, 1956a, pp. 54, 55, 56, 57, 58, 62, 63; 1956b, pp. 440, 441, 442, 443, 444, 448, 449). The movements of the bony parts probably do not differ essentially in the two minor top functions. There are, however, some differences: during injection the poison-fang, which has to be stung into the prey, is more erected than during swallowing; the maxillare turns over a smaller angle during the swallowing-act than during the act of the poison injection; when both jaws are placed in the most forward position, the neck participates, but in a way different for the two minor top functions. The apparatus for injection and for swallowing consists of the lower jaw, of a construction containing the

maxillare, the old upper jaw and the supratemporale, and of the bending and stretching of the neck region and the forward movement of the cerebral skull. In connection with the way of killing and swallowing we find a loosely connected upper jaw and lower jaw with an independent situation of the jaws of both sides and with a movement independent of each other (after the fixation at one side, upper and lower jaw at the other side relax, move forward, close, *etc.*); the angle of the mouth shows a far caudal position. The upper jaw construction mentioned above, shows two fixed points: a) the place of attachment of the rostral end of the supratemporale to the cerebral skull; this place of attachment depends on the position of the bony dorsal wall of the statical organ, the most lateral position of the supratemporale depending on the breadth of the bony labyrinth in the dorsal surface of the cerebral skull; b) the place of attachment of the dorsal end of the maxillare to the cerebral skull. The mentioned chain of bony elements shows four places where two adjoining skeletal elements show a topographically movable connection: i) between the caudal end of the supratemporale and the dorsal end of the quadratum; ii) between the ventral end of the quadratum and the caudal end of the old upper jaw; iii) between the pterygoid and the transversum; iv) between the rostral end of the transversum and a point on the maxillare a little ventrally of its point of articulation with the cerebral skull. Finally the old upper jaw turns around the longitudinal axis of its rostral parts, so that quadratum and supratemporale also turn medialwards. The quadratum can turn lateralwards with its distal point, which is possible by a bend in the pterygoid and a rather loose connection of the pterygoid with the quadratum. The precise adaptation of the bony elements to each other, thus forming a total construction, should give only one possibility of movements. There is, however, a rather loose connection of the tissue around the joint and moreover, the movement is not exactly determined in one plane. — As to the muscles of this system, we find the following facts (DULLEMEIJER, 1956a, pp. 60, 61, 63, 66; 1956b, pp. 446, 447, 449, 452). The turning of the maxillare over an angle of about 90°, cannot be caused directly by muscles attached to the maxillare, but this turning must be effected by a pulling-act from caudally, caused by a muscular system *via* a caudalwards running upper jaw, the muscles being situated between this upper jaw and the neurocranium. The place of attachment and the position of the musculus levator pterygoidei and of the musculus protractor pterygoidei is bounded rostrally by the position of the eye. The position of the eye in the lateral dimension is in the first place determined by the outer surface of the head, which in its turn is determined by the breadth of the maxillaria and the space between the two maxillaria occupied by the olfactorial capsule, and in the second place the position of the eye is determined by the creeping way of living which includes a rather small height of the cerebral skull and a lateralward extension of the relatively big size of the brain and thus of a rather broad shape of the cerebral skull. The most rostral place of attachment of the musculus levator pterygoidei on the old upper jaw is the point that can more or less remain in position in lateral projection; this point, however, must remain caudal to the orbita in every position of the jaw. The attachment of the musculus protractor pterygoidei to the caudal part of the old upper jaw shows a very small angle between the muscle fibres and the pterygoid, so that the fibres of this muscle must have a length of about twice the distance of the rostral displacement of the articular point with the transversum on the maxillare.

(4) The conditions found in *Crotalus* differ in some respects from those found in *Vipera* (DULLEMEIJER, 1959, pp. 928-930): in *Crotalus* the position of the muscle, effecting the movement of the maxillare, is of secondary importance; there is a primary relation between the size of the prey and the length of the upper jaw; the presence of a "pit" in the maxillare rostralwards of the orbita entails a rostro-dorsal position of the joint between maxillare and praefrontale (in *Vipera* rostro-ventral to the eye), a rostro-dorsalward movement of the joint between maxillare and transversum during the erection of the maxilla (in *Vipera* rostro-ventralwards), and a still more ventral position of the transversum in resting-position than in *Vipera*.

(5) A number of separate muscles render a service in the movement of the lower jaw and of the head in relation to the neck for the purpose of catching food in *Phalacrocorax carbo sinensis* (Shaw & Nodder) (DULLEMEIJER, 1952, pp. 99-100). These separate muscles are correlated with their particular function, but as members of a whole muscle system they are correlated with the entire function of the system; thus they have an entire influence on the whole skull; the whole muscle system and every muscle is correlated with the whole skull. The function of a muscle is correlated with its extension and thus with its volume, which is limited on one hand by the external shape of the head and on the other hand by the maximal plasticity of the other functional components of the head. The function of a muscle is correlated with its length, resulting in the extent of its shortening and its lift and thus with the position of its ends and with the areas of attachment. The function of a muscle, especially its strength, is correlated with its "physiologic section", and thus with its aponeuroses, *etc.* and with its character as a composite muscle. On account of the way of catching food in *Phalacrocorax* one may expect the occurrence of a strong adductor system (composite muscles; the necessary rather high lift is attained by the fact that the muscle extends far dorsalward and caudalward on the os accessorium, thus as far as the cervical region, the distance to the caudal end of the cerebral skull being too short). One may also expect a weak depressor system (no remarkably strong aponeuroses; especially on the lower jaw a small place of attachment). One may also expect strong cervical muscles (the power is of greater importance than the lift; the lateralward and ventralward moving of the head is of greater importance than the dorsalward; lateral extension of the attachment of some of these muscles) (DULLEMEIJER, 1952, pp. 99-101).

In the fifth place we think of all muscles in the head which in their function, position, *etc.* are influenced by the outer shape of the head.

Examples: (1) This occurs in *Vipera berus* (L.); here the outer shape of the head and the cerebral skull is in accordance with the peculiar way of moving by creeping (DULLEMEIJER, 1956a, pp. 58, 63; 1956b, pp. 444, 449).

(IV) (iv) *The relation form-function in a consideration of a general connection of form and function*

The problem of the relation of form to function is a typical biological one. We do not find it in other natural sciences in this form. This is due to the fact that biology has developed along a number of more or less separate lines of investigation, in this case as morphology and as physiology. It is also due to the fact that the biological interest in this problem starts with bigger parts of the body and with top functions. Now, bigger parts of the body show a complicated structure on the one hand with a number of functions on the other hand. Top functions show a number of smaller functions, perhaps bound to various parts of this complicated structure.

This study of bigger parts of the body which as a rule show a complicated structure and a number of functions, leads in many cases to a comparison with technical products. This comparison of biological objects with technical ones, has led to principal questions about its admissibility (see VAN DER VAART, 1958).

A first step in this third approach to the consideration of the relation form-function is made by the consideration of functional components. These functional components form together a pattern, a structure or an architecture. The functions of these functional components together form a harmonic totality or a functioning pattern. This will be dependent on the rules existing between form and function. Thus functional anatomy acts as an auxiliary discipline for structural morphology, but it has its consequences for the methods of research into the relation of form to function (DULLEMEIJER, 1957).

As we have seen above a functional component may in some cases be a primary element with a strict and direct relation between form and function, but in most cases it will be a secondary element without a simple relation between form and function, this relation not being strict (DULLEMEIJER, 1957).

To consider a rather simple functional component, consisting of a skeletal element to which muscles are attached, DULLEMEIJER (1958, p. 85) draws attention to the following facts.

The function of the muscle influences almost indistinguishably the size, the shape, as well as the structure of a bony element. The muscle exercises a certain strain on the bony element; to resist this strain the bony element must have a certain shape and structure (DULLEMEIJER, 1958, p. 85). The shape and the structure of the skeletal element depend on:

1. the kind of construction (a statically determined or an instable construction, or in a few cases a statically undetermined construction);
2. the kind of the skeletal material (the mechanical properties of the bony material and its differences in the different classes of Vertebrata);
3. the strain and the partition of the strain in the construction;
4. the kind of strain, such as flexion, compression or tension;
5. the influence of the other functions (DULLEMEIJER, 1958, p. 85).

Flexion in one plane mainly results in a shape of a bony element which will be flat, ending in sharp rims (shape of the ectopterygoid, wings of the pterygoid, both in the Viperidae; such wings or margins have no relation to the manner of attachment of muscles) (DULLEMEIJER, 1958, p. 85).

The inner structure or the build of a bony element is influenced very considerably by the muscle strains: it can be compact, so that a minimum size occurs with a maximum resistance (as with the ectopterygoid in many snakes); it can also contain inner holes, the mass of bony tissue being concentrated in the spongiosa (the direction and shape of the spongiosa is undoubtedly influenced by factors of strain; the position of the trabeculae is dependent on other factors (DULLEMEIJER, 1958, pp. 85/86). In a certain section, as for instance a cross section, the bony mass must have a certain surface or the product of surface and distance to a neutral axis must have a certain value. The distribution of bony mass, however, is very variable and depends on the course of the blood-vessels and nerves and on the presence of other structures, *e.g.* the spongiosa in the caudal part of the lower jaw of *Vipera*, the middle part of the pterygoid and the maxilla in *Vipera* (DULLEMEIJER, 1958, p. 86).

Still we expect that in more and more cases another approach to the relation of form to function than a simple independent description in juxtaposition, may be possible now and in the future.

Two ways are already visible now and loom up in the near future.

The first way uses a coefficient indicating the relation of form to function (DULLEMEIJER, 1956a, pp. 3-4; 1956b, pp. 389-390), or tries to find such a coefficient. This is in line with the law of BOYLE-GAY LUSSAC, which is based on the general relation of volume to pressure in gases at a certain temperature. It is also in line with the introduction of the coefficient of velocity or of acceleration, indicating the general relation of way and time in certain moving bodies. Thus according to DULLEMEIJER (1958, p. 86; see also SARKAR, 1960, p. 10) we can describe the influences of form *etc.*, function, surrounding elements and outer shape in the following way: if x is the function and y the structure, then there is the relation $y = a(x)$ in which a is the factor which represents the rules of realization; the influence of the surrounding elements can be indicated by b; so that the structure is $y = b(a(x))$; sometimes b may be influenced by the outer shape. SARKAR (1960, p. 10) has expressed the same thought in the following way, saying that we can understand the shape of a functional component, muscles as well as skull elements, from the rules existing between form and function which can be expressed as $U = f(F)$, where U denotes the form, F the function and f the factor representing the rules of realization. If we indicate the influence of the surrounding elements and of the totality by f', we get as expression $U = f'(f.F.)$, also found by the non-comparative method, studying a number of specimens of one species. This method can find a complementary method by the comparative one on related species.

The second way uses one other empirism instead of the two separate empirisms of form and function, or tries to find such an empirism embracing the two other ones. This is in line with the use of volume instead of length, breadth and height. It is also in line with the use of lines of force instead of form and pressure or tension.

A first application of this second way is made when we introduce volume or weight in our problem of the relation of form and function. The volume is proportionate to cross section and to length, but as to the functions it makes a difference whether the same value of the product is due to a high value of the cross section or to that of the length. The power of a muscle is proportional to its cross section and the lifting-range is proportional to its length. Thus the knowledge of the value of the volume of a muscle has a provisional value only for our knowledge of the functions of the muscle; we need the value of the length, of the cross section and also the knowledge of the position of the muscle.

Examples: (1) The relation of the weights of the right and those of the left muscles in the asymmetrical *Pleuronectes platessa* L. is used by De Blok (1955, 1956, 1957) to understand the relation of form and function in muscles in this asymmetrical fish, but it is especially used as a measure for the asymmetry. Though he says that additional differences in position and shape have also been taken into account (De Blok, 1955, p. 659) and though he knows that cross section and length have their specific value in the functions of muscles (De Blok, 1955, p. 671), he gives no exact data about the position and shape of the muscles. — We may consider the body of a flatfish, such as *Pleuronectes platessa* L., as a system of two lenses, a plano-convex and a concavo-convex lens. The plano-convex lens represents the morphological left half, acting as the physiological underside of the body with its flat bottom. The concavo-convex lens represents the morphological right half, acting as the physiological upper side of the body with the convex eye-side (De Blok, 1955, p. 670). Consequences of the comparison with the system of lenses are: 1) the length of the cross section through the convex outer surface of the right side is longer than the length of the cross section through the flat outer surface of the left side, if both lenses are supposed to possess the same volume (first principle), which entails, with an equal volume for both halves of the body, that the muscles in the right body half which must span a greater distance in the dorso-ventral direction would have to be thinner, the more so as the muscles are situated more superficially; 2) the thickness of the cross section of the plano-convex lens (left half of the body) is greater than that of the concavo-convex lens (right half of the body), if both lenses (both halves of the body), are supposed to possess the same volume (second principle), which entails that the muscles in the right body half, running in the dorso-ventral direction, which shows a lesser thickness, must be thinner and would have to show a greater length (De Blok, 1955, pp. 670-671). These two principles of the two-lenses model can be marred and modulated by the functional demand (third principle), which may give rise to another cross section of a muscle in the case that the function of the muscle may demand this (De Blok, 1955, p. 671). For the architecture and the situation in the orbital and praeorbital regions the adjustment of the animal to the rotation relative to his environment is decisive (fourth principle); one of the consequences of this rotation of the most rostral part of the head with the mouth to the morphologically left side or to the physiologically underside is the fact that in a caudo-rostral direction the skeletal elements are progressively heavier in the left body side than in the right one; the muscles, however, are not discussed (De Blok, 1955, p. 675). In my opinion this fourth principle may entail a lengthening of the right muscles in the most rostral part of the head and a shortening of the left muscles. In the postorbital region the three first principles are first and foremost in determining the relation in weights (De Blok, 1955, p. 675). Of the first three admitted principles only two can apply at the same time (De Blok, 1955, p. 674).

A second application of this second way (using one other empirism instead of the two separate empirisms of form and function) is made when we introduce moments of resistance to bending, calculated from sections of the skeletal element, leading to a surface of moments to be expected and thus to a shape of the skeletal element to be expected. In the case that, or as far as the shape of the skeletal element is determined by muscles attached to it, we get an insight in the problem of the relation of form and function of this skeletal element. This has been done by Dullemeijer (1956a, pp. 76 *sq.*; 1956b, pp. 462 *sq.*) (See also Dullemeijer, 1957, for some historical facts; for critical notes see Van der Vaart, 1958, pp. 158-164).

CHAPTER (V)

ECOLOGIC-MORPHOLOGICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

(V) (i) *Introduction*

Also of this ecologic-morphological examination of the projections, deepenings and undulations of the surface of the skull in relation to the attachment of muscles we may expect that this should yield highly important results. We know that there must be a close connection between these projections, deepenings and undulations, and the abiotic and biotic environment in which the animal lives and in which the said elements of the surface of the skull function.

Many stray data about the ecologic morphology of these elements of the surface of the skull are already known.

By virtue of the nature of the ecologic morphology we can distinguish two main fields within this subscience (VAN DER KLAAUW, 1948a): an ecologic morphology of parts of the body, so in our case of the elements of the surface of the skull, and an ecologic morphology of the animal as a whole, which can involve a certain development of these elements of the cranial surface.

(V) (ii) *Ecologic morphology of parts of the body*

The ecologic morphology of the elements of the cranial surface correlates the form of these elements and the environment in which the animal lives. It is obvious that in establishing this correlation between form and environment, the function of that element as a third party unmistakably plays a part. We noted previously that in the functional anatomy form and function are correlated. Naturally, in establishing this correlation, the environment in which the animal lives unmistakably plays a part as a third party. Consequently, in establishing the two correlations mentioned the accent is different, which in the case of the projections, deepenings and undulations of the surface of the skull does not lead to any other facts or opinions. An examination of the general mechanic laws in a functional sense would not furnish any new opinions, if we should apply them to the specific environment-situation. Even if we should consider the said correlation between environment and form of the elements of the cranial surface from the standpoint of the preservation of individual life as a requirement for life, it would not lead to any new insights in our case.

The rare cases of a stereometric connection between the form of a part of the body and the environment are not applicable to our subject material.

(V) (iii) *Ecologic morphology of the organism as a whole*

The ecologic morphology of the organism as a whole is the second field of ecologic morphology (VAN DER KLAAUW, 1948a, pp. 87 *sq.*). In our case the question concerns the consequence of the correlation between certain qualities peculiar to the organism as a whole, and the environment, for the projections, deepenings and undulations on the surface of the skull.

The qualities referred to, peculiar to the animal as a whole, are in Vertebrata: the size and weight of the animal, the specific gravity of the animal, the position of the centre of gravity of the animal and some special forms of the general shape of the body, in which four qualities there is a connection with the environment in which the organism lives. These four qualities of the organism result in certain qualities of the parts of the body. In our case the question concerns the consequence for the way of attachment of muscles on the surface of the skull and with it for the development of the projections, deepenings and undulations of the cranial surface.

(iii) (1) The size and weight of the animal

As to the size and weight of the animal, it should be examined whether it can be traced back by a difference in the projections, deepenings and undulations of the cranial surface in very big and very heavy water-dwelling animals on the one hand and in very small and very light birds actively flying in the air, on the other.

In water-animals the skull can be voluminous and so cartilaginous for a considerable part. A thick cranial wall may involve that the surface of attachment for muscles in its position is relatively independent of the internal wall of the skull (which internal wall covers the cavity for the brain), which might carry with it that no cristae or spinae are required as a means to make the direction of the surface of attachment independent of the general position of the surface of the cranial wall. Local occurrence of cartilage in voluminous skulls of water-animals may imply the absence of cristae and spinae in these places of the cranial surface for the attachment of muscles.

The small and light bird may have a small, light skull with thin cranial walls as a result. This may entail the development of cristae and spinae for the attachment of muscles.

Apart from this it should be examined among animals living in the same milieu, such as for instance the land animals, whether it can be traced back by a difference in the projections, deepenings and undulations of the cranial surface in very big and very heavy animals on the one hand and in very small and very light animals on the other hand.

(iii) (2) The specific gravity of the animal

As regards the specific gravity of the animal, we wish to point out that a high specific gravity of the whole body might be caused by a large mass of bone, since bone has a high specific gravity in relation to other tissues. Thus a low specific gravity of the whole body might be caused by a small mass of bone, accompanied by a thin cranial wall, *etc.*

It should be investigated whether any difference in the elements on the surface of the skull bears on the difference in specific gravity of the whole body, in the specifically very light fliers among the birds with a very thin bony skull, and in the non-flying birds with a high specific gravity.

It should also be examined if any difference in the elements on the surface of the skull bears on the difference in specific gravity of the whole body, in the specifically heavy fishes living on the bottom of the deep-sea and having a heavy dermal armour on the one hand, and in the surface-fishes with a lower specific gravity on the other.

(iii) (3) The position of the centre of gravity of the animal

Regarding the position of the centre of gravity of the body as a whole, we draw attention to a few possible consequences. Among the land-dwelling mammals it is conceivable that in a nearly equal position of the vertical projection of the centre of gravity of the body as a whole, between the points of support of the four extremities on the substratum, there occur either a very heavy head and skull, placed on a short cervical spinal column, or a light head and skull, placed on a long cervical spinal column. It will have to be examined what is the difference in the surface of the skull in the two extremes mentioned.

(iii) (4) Special forms of the general shape of the body in some animals

Concerning certain special forms of the general shape of the body correlated with the character of the environment, we mention, as being of importance for our subject, firstly the stream-lined shape of the body in rapid swimmers, the shape of the head being a gradual continuation of the shape of the body, and secondly the cylindrical shape of the body in diggers, a conical head with conical skull being in keeping with it.

It should be investigated whether a certain way of attachment of muscles and a certain development of the projections, deepenings and undulations on the surface of the skull relate to the shape of the head of rapid swimmers. With this it will be of great influence what is the shape of the outer circumference of the head in proportion to that of the skull, whether the latter follows the former everywhere at a short distance, or whether the skull is situated, over larger or smaller fields, at a greater distance from the outer circumference of the head than in the other fields.

It will have to be examined if the conical surface of the skull in diggers is accompanied by a tangential attachment of muscles to the skull or by a "dune-edge"-attachment or "dune-rim"-attachment of muscles to the skull (see COOL, 1952, pp. 639-641 on the rostral attachment of the musculus longissimus dorsi to the caudal surface of the fronto-parietale in *Rana*) (see this paper on p. 196).

CHAPTER (VI)

ARCHITECTURAL-MORPHOLOGICAL OR STRUCTURAL-MORPHOLOGICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

(VI) (i) *Introduction*

With the architectural-morphological or structural-morphological examination of the projections, deepenings and undulations of the surface of the skull in relation to the attachment of muscles, we enter on an important field of investigation. These elements of the surface of the skull are most closely connected with the structural scheme.

In the architectural or structural morphology an inquiry is made into the correlation of the form, build and finer structure of all organs, of all organ systems, of all functional components and all parts of the body, all within the common outline and all together entirely filling the space within this common outline. When the elements are integrated into a totality, it is obvious that one element can be influenced by many others and that the mutual influence can be rather complicated. Moreover, the totality is influenced by some general requirements as a determined outer shape, a certain weight or volume; this outer shape has of course its influence on the elements (DULLEMEIJER, 1958, p. 86). The data obtained by analysis in this field are combined into the architectural or structural scheme by a synthesis. It depends on the way of analyzing and abstracting, whether the facts found in this way tend to such a synthesis. In functional anatomy, as we have seen, the result of our analyzing and abstracting can be the form, *etc.* of an entirely separate organ or functional component, *etc.* For a synthesis into the architectural or structural scheme, however, we need as important facts the knowledge of correlating facts, of connections, *etc.* with surrounding or neighbouring elements, thus the knowledge of the factors, also those found in the neighbourhood influencing a certain element, as well as the influences of this element on the neighbourhood (see the diagrams in DULLEMEIJER, 1956a, fig. 38, table II; 1956b, fig. 38, table II; 1959, figs. 51, 52, 53, 54; and the diagram in SARKAR, 1960, fig. 38 on p. 108).

This is expressed by DULLEMEIJER (1956a, pp. 74, 75; 1956b, pp. 460, 461; see also SARKAR, 1960, p. 97) in his view that we need to know on the one hand the factors determining a functional component, that is not only the mechanical factors determining its shape, but also the "spatial factors", and that we need to know on the other hand the "position of the component" which in its turn together with the mechanical or physiological requirements has a "structural influence" on the neighbouring elements.

This architectural or structural scheme may be that of an individual, of various individuals of one species of the many species of one genus, of the many genera of one family, of the many families of one order, of the many orders of one class, of the various classes of one phylum.

This architectural-morphological or structural-morphological view concerns firstly the establishment of the architectural or structural scheme peculiar to the individual, the species, the genus, the family, the order, the class, the phylum; secondly the question is as to the special formation or effect in every inferior systematic category of the architectural or structural scheme of the more comprising systematic categories. Of a certain species of animal the form and structure are a particular specialization based on functions peculiar to that species and based on an environment fitting in with it, of the architectural or structural schemes of the various higher systematic categories to which the given species of animal belongs. This does not only apply to the species, but also to the more comprising systematic categories. Thus also the elements of the surface of the skull are a distinctive adaptation of the architectural or structural scheme in its various stages to the distinctive functional requirements and to the distinctive environment.

As to the projections, deepenings and undulations of the skull, as to the form, build and finer structure of the muscles and of the aponeuroses, tendons, *etc.*, the architectural or structural scheme will reveal itself in a number of characters.

As to the projections, deepenings and undulations of the surface of the skull we find a correlation with the architectural or structural scheme regarding the following points: (ii) the substance of which the skull is made; (iii) the general symmetry of the skull as a whole; (iv) the general form of the surface of the skull as a whole; (v) the general form of the surface of the functional components; (vi) the position of certain parts of the skull which defines the pattern of the skull and of the head; (vii) all sorts of qualities of the skull, correlated with other functions.

(VI) (ii) *Correlation with the substance of which the skull is made*

The substance of which the skull is made might be cartilage, partly ossified cartilage, almost entirely ossified cartilage, and covering bone. In this respect the architectural or structural schemes are widely divergent.

In entirely cartilaginous skulls, as occur in Marsipobranchii, Selachii and Rajidae, the architectural or structural scheme of the skull results in the absence of cristae and spinae for the attachment of muscles

(MANGER CATS, 1951, pp. 193, 299 on Squaliformes; VAN DEN ASSEM, 1952, p. 673 on *Squalus acanthias* L.). In such skulls formations resembling cristae occur as "separating cristae" between surfaces of attachment of muscles. This is in contrast with bony skulls, in which, however, such "separating cristae" can also occur, as *e.g.* the crista in the dorsal median of the cerebral skull in Primates, which forms the separating plane between the surfaces of attachment of left and right musculus temporalis.

Examples: (1) In Squaliformes a muscle never attaches along a protruding margin with a sharp edge, but always in the shallow depression next to the sharp edge, where the surface is curved inwards, showing an excavation to which there is a musculous attachment; in other cases in this systematic group the musculous attachment occurs along inclines of the surface of the skull (MANGER CATS, 1951, pp. 299, 300).

(2) In *Squalus acanthias* L. the musculous attachments generally occur in shallow depressions in the cartilage. In the musculus coraco-arcualis V, however, the place of attachment is found on the flat cardiobranchiale without a distinct difference with the surrounding cartilage. A clear and direct relation can *e.g.* be found in the arci branchiales: an attachment of a larger part of the musculus coraco-arcualis to the ceratobranchiale corresponds with a more extensive place of attachment on that cartilaginous element (VAN DEN ASSEM, 1952, p. 673).

With regard to a possible character of entirely cartilaginous skulls we draw attention to the fact that round tendinous elements or round tendons are lacking in the part of the head in the Squaliformes investigated by MANGER CATS (1951, pp. 192, 298), in the head of *Squalus acanthias* L. investigated by VAN DEN ASSEM (1952, p. 673) and in the head of *Raja batis* L. investigated by GOTTENBOS (1956, p. 734).

With regard to another possible character of entirely cartilaginous skulls we draw attention to the fact that plate-like aponeuroses show a tangential attachment to the cartilage (MANGER CATS, 1951, pp. 197, 198, 199, 299, 300).

In partly ossified skulls, as occurs in Amphibia, there must be a correlation with the projections, deepenings and undulations of the surface of the skull. In Amphibia we find a skull which is originally partly cartilaginous, while this cartilage ossifies only late and that only for a small part.

Examples: (1) In *Rana esculenta* L. we find in some muscles an attachment partly to dermal bones, partly to cartilage, which in a number of cases ossifies in older skulls (COOL, 1953, p. 243). In *Rana esculenta* L. the musculus intertransversarius capitis inferior is attached to the cartilage lying laterally of the exoccipitale, the lateral part of this place of attachment being ossified in older skulls (COOL, 1952, p. 642). In *Rana esculenta* L. an attachment of aponeuroses occurs to ossified parts (in that case mainly to cristae), as well as to cartilaginous parts (in that case a tangential attachment is found) (COOL, 1953, pp. 241-243).

In entirely ossified skulls or in almost entirely bony skulls, as occur in Reptilia, Aves and Mammalia, the architectural or structural scheme is no unity regarding the projections, deepenings and undulations of the surface of the skull. Here it is in the first place decisive whether the cranial wall is thin or thick. In the Aves with their very thin cranial walls, we find a strong development of cristae, processus, *etc.* In the Mammalia with a thick cranial wall we find tangential muscular attachments to a smooth cranial surface having "lines" and "fields". For the Reptilia nothing is summarized in literature.

(VI) (iii) *Correlation with the general symmetry of the skull as a whole*

Most skulls of Vertebrata show a bilateral symmetry. With regard to the muscles we have to deal here with muscles occurring on the left and on the right side where they show the same or a similar development, but also with unpaired muscles running from the right side to the left side.

Curious features are found in the distinctly asymetric head as occurs in *Pleuronectes platessa* L. (De Blok, 1955, 1956, 1957). With regard to the line which represents the section through the imaginative plane which is along its whole length situated at equal distances from both sides of the body, in comparison to the section through the median plane of the animal (this median plane in the asymmetrical head in the consideration of this head as a system of two lenses, connects the plano-convex lens representing the morphological left side, acting as the physiological under side of the body with the flat bottom, and the concavo-convex lens representing the morphological right halve, acting as the physiological upper side of the body with the convex eye-side), we find three different parts in the head and in the skull (De Blok, 1955, p. 677): a) the most caudal part of the skull; here the left side is heavier: of some muscles of the branchial skeleton the left ones are heavier (De Blok, 1955, p. 672); b) the rest of the postorbital part of the head; here we find a larger capacity and heavier elements on the right side than on the left side; 18 muscles from the right body side proved to be heavier (against 12 from the left body side) (De Blok, 1955, p. 672); most muscles of the postorbital part of the head are heavier on the right body side and so possess a greater volume (De Blok, 1955, p. 674); the greatest asymmetry in weight is shown by the musculus levator arcus palatini in favour of the right one, coinciding with a considerable extension of its two places of attachment in a rostral direction (De Blok, 1957, pp. 84, 87); the musculus adductor arcus palatini is also heavier on the right side coinciding with greater length of the muscle fibres in relation to the greater mobility of the elements of the right side (De Blok, 1957, p. 87); the musculus adductor mandibulae is also heavier on the right side which is in accordance with the difference in area, which lies in a larger fenestra together with the right eye; the difference in weight of the part $A_{2,3}$ of this muscle is much larger, that of the part A_1 is also in favour of the right side though only to a very small degree (DE BLOK, 1956, pp. 242, 244; 1957, pp. 84, 88-89); c) the orbital and praeorbital part; here we find on the right side a considerably larger capacity, accommodating the eyes and we find on the left side heavier skeletal elements. In the last region the median plane has shifted very far to the left, while it is brought back into the axis of the mouth as soon as the mouth is opened and the jaws protruded; of some muscles with a praeorbital insertion the left ones are heavier (DE BLOK, 1955, pp. 672, 675); the consequences of the far left position of the mouth for the architecture of the skull extend their influence by means of the attachment of muscles as far as the orbital and postorbital regions (DE BLOK, 1957, p. 77). — According to DE BLOK (1955, p. 677) in region a) perhaps the principles (2) and (3) obtain, region b) is the region of principles (1) and (3) and in region c) principle (4) obtains (for these four principles see p. 229). According to principle (1) the length of the cross section through the convex outer surface of the right side is longer than the length of the cross section through the flat outer surface of the left side. According to principle (2) the thickness of the cross section of the plano-convex lens (left half of the body) is greater than that of the concavo-convex lens (right half of the body). Principle (3) expresses the functional demand which can modulate the first two principles. According to principle (4) the rotation relative to the environment is decisive. — If only principle (1) and (2) are valid we may assume that in the case of a muscle which can be considered as an elongated rodlike element lying at the right side, the longitudinal direction has increased a-times and the two other dimensions to a lesser degree, *viz.* only a/b-times. In that case volume and weight will be a^3/b^2-times as great in the element on the right side as in that on the left side. In that case the lifting-range which is proportional to the length, has increased a-times and the power of the muscle which is proportional to the cross section has decreased a^2/b^2-times (DE BLOK, 1955, p. 671).

Another factor in the morphology of this asymmetric head of *Pleuronectes platessa* L. is the course of the curvature of the body axis which rostralwards runs considerably dorsalwards. Owing to this the longitudinal axis of the cerebral skull is tilted in this sense that its caudal end is situated relatively far dorsalwards. So the part of the body musculature situated dorsally of the cerebral skull has a rather small volume; in swimming it effects the movement of the in itself immovable head in relation to the foremost part of the spinal column; its counterpart is the very strongly developed musculus sternohyoideus (DE BLOK, 1955, p. 678).

The bilateral asymmetry in *Pleuronectes platessa* L. has disappeared also in another respect: the top of the right rostral cone into which the right musculi obliqui have their origin, lies in the left orbita which is reached by this right cone through a "window" in the septum interorbitale (DE BLOK, 1956, p. 242).

(VI) (iv) *Correlation with the general form of the surface of the skull as a whole*

In this respect we mention the case of a skull with a stream-lined surface and the skull with a conical form of the surface as occurs in diggers. In these cases there will be no cristae or spinae, *etc.* We also mention the flatness of the skull in the rays; these fishes also show a distinct flatness of the entire body and the head (GOTTENBOS, 1956, p. 736).

A transitional shape of the head between a sharp conical shape and a more or less blunt form at the anterior end, as a compromise, is found in *Sphaeroides oblongus* (Bloch) (SARKAR, 1960, pp. 86 *sq.*, 91 *sq.*). This head is more or less conical with a gradual increase of the cross section from rostral to caudal and is without remarkable extensions. Such a sharp conical shape is found in fishes which move fast and which can suddenly change their positions, the latter being the case in *Sphaeroides*. The bluntness of the rostral end is due to the presence of a pair of heavy, beak-shaped jaws, necessary for the particular way of feeding, but there is also a reverse influence of the outer shape on the jaws. The shape and position of the jaw apparatus and its function have a decisive influence on the surrounding skeletal elements, *viz.* the palatinum and the pterygo-quadrate bar. This transitional outer shape of the head encloses also the many and voluminous strongly developed muscles which these heavy jaws need for biting. They occupy a large space in the head and a large area for their attachments. The influence of these muscles on the different parts of the skull by their attachments and distribution is remarkable, *e.g.* the broad and projected praefrontale, the inwardly directed pterygoid plate, the broadness of the praeoperculum, the prominent hyomandibular crest, *etc.* We may also say that the shape and position of the jaw apparatus has a decisive influence on the position and structure of the muscles which are responsible for their movements. The muscles in *Sphaeroides oblongus* (Bloch) take all the space available, be it sometimes in an unfavourable working-position (p. 94). The muscle A_1 runs from the ventral part of the praeoperculum to the skeletal lower jaw; the extreme rostral end of the lower jaw which would offer the most suitable position, cannot be used owing to the position of the buccal cavity; the attachment of the aponeurosis (2) has to be on the dorsal side and the caudo-dorsal area of the lower jaw is the only available place for the attachment of this muscle, as the remaining areas of the lower jaw are occupied by the thick infold of the skin, the nerves and blood-vessels, the connective tissue band and the aponeurosis (3) of musculus adductor mandibulae A_2. On the space available on the pterygoid plate, the upper half of the praeoperculum and partly on the hyomandibular crest for the course and attachment of the muscles depends the shape of the parts A_2 and A_3 of the musculus adductor mandibulae. The space available to the caudal extensions is very limited in breadth though rather long. Consequently the muscle has to be narrow. The caudal parts are very narrow extensions; they are extended far back to the caudal part of the skull and are in line with the main body of the muscles. The lengths of the parts A_2 and A_3, without these narrow caudal extensions, are about twice the distance moved by the jaws, which gives sufficient scope for the functioning of the muscles. By their contraction these narrow caudal extensions bring the other parts of the muscle A_2 and A_3 to convenient working-positions. The muscle fibres of the elevated part of muscle A_3, which is attached to the rostro-dorsal area of the hyomandibular crest, are directed more dorsally instead of having a rostral course and thus this part of the muscle shows another example of adjustment in a given space. It might be said that some muscle fibres of this portion of the muscle could find an area for attachment nearby and they could also fill up the spaces available to them. The available area of the caudal attachment of the musculus adductor maxillae $A_1m\beta$ on the hyomandibular crest is the narrow rostral border of this crest, which explains the aponeurotic character of this attachment (the rostral attachment to the maxilla is broad), whereas the caudal attachment of the musculus $A_1\alpha$ gets a broader area on the praeoperculum for the greater part of its caudal attachment (the rostral attachment to the maxilla is a narrow aponeurotic one). Within the area bounded by the dorsal part of the maxilla, the projecting praefrontale and the dorsal part of the pterygoid plate, the three parts of the muscle $A_1m\alpha$ are adjusted. The space available for the attachment on the squamosal process and on the rostral part of the operculum for the pars lateralis of the musculus dilatator operculi and on the postfrontale and on the spina of the operculum for the pars medialis of this muscle determine the shapes of these two parts of this muscle, being long resp. broad. The positions of the muscles A_2 and $A_1\alpha$, as regards their caudal parts in particular are influenced by the positions of the musculus dilatator operculi and the musculus levator operculi.

(VI) (v) *Correlation with the general form of the surface of the functional components*

We wish to point out that a spherical surface of the cerebral skull has its consequences for the form, the size, the place and the position of the places of attachment of muscles and for the way of attachment.

(VI) (vi) *Correlation with the position of certain parts of the skull which defines the pattern of the skull and of the head*

The pattern of skull and head can be taken in an architectural sense, sometimes in a stereometrical sense.

We indicate that the position of the orbita and that of the joint of the jaw together can be deciding for the direction in which certain jaw muscles are running and consequently also for the way of attachment to the skull, and so for the elements in question on the surface of the skull. This is very striking in the cases that such a muscle must make a bend round the curved back wall of the eye or of the orbit. The position of the orbita and the way in which the eye looks along the bill in *Ardea cinerea* (L.) is correlated to the position of the rostral point of the attachment of the masticatory muscles to the centre of the eye (Bas, 1957, p. 485). The position of the bony elements to which a muscle or a number of muscles is attached, is correlated to the size of this muscle or muscles, as is illustrated by the distance between cerebral skull and the upper jaw and the lower jaw in *Bitis arietans* Merrem and in *Trimeresurus albolabris* Gray; correlated to it is a different course of the muscles in both species, a different direction of the muscular force and a different structure of the bony elements (Dullemeijer, 1958, p. 82).

The position of such parts of the skull is connected with certain features in the way of living of the species.

A correlation with the architecture of the skull and head in a general sense should be present if the shape of the skull and the available space in the head should determine the position of a muscle and if it is not the function of the muscle which primarily affords a criterion for the determination of its position; a muscle might produce, however, an excavation by the tension which it exercises upon the place of attachment (for literature see Manger Cats, 1951, pp. 191, 299; see also Dullemeijer, 1952, p. 100).

The dorsal surface of the cerebral skull in the Viperidae, probably a functional requirement for crawling, is in line with the body shape; the dorsal surface in the small snakes shows no difference with the big snakes in this respect; in the small snakes the relatively bigger brain gives rise to a ventral spherical enlargement of the cerebral skull (Dullemeijer, 1958, p. 86).

The area of attachment of a muscle can also be influenced or determined by the course of nerves and blood-vessels, the course of which has a certain priority (see Dullemeijer, 1956a, pp. 91/92; 1956b, pp. 477/478 on the place of attachment of the musculus adductor mandibulae internus pterygoideus in *Vipera berus* (L.) ventralwards to the opening for a nerve and for blood-vessels on the medial surface of the lower jaw).

(VI) (vii) *Correlation with all sorts of qualities of the skull, correlated with other functions*

The correlation of all sorts of qualities of the skull with other functions can be formulated according to Cuvier's "principe des corrélations des fonctions".

We point out that the form, the size, the place and the position of the places of attachment of certain muscles and the way of attachment of these muscles will show a connection with the same qualities of other muscles, *e.g.* those for moving the jaws with those for moving the eyes.

As to the form, build and finer structure of the muscles we find as well a correlation with the architectural or structural scheme of the head as a whole. General rules in this field are:

1) The composite muscle, interrupted by a number of myosepta of non-muscular tissue which connect a number of segments of a muscle, is more common in the lower Vertebrata than in the higher Vertebrata.

2) The composite or combined muscle is more common near the centre than near the periphery.

3) The single, non-branched, non-forked muscle is common in the highest Vertebrata.

A special case regarding the form, build and finer structure of the muscles occurs in the rays with their extreme flatness of the skull, of the head and of the body as a whole. In the rays the muscles are often broad and flat and consist of a muscular and an aponeurotic part; one gets the impression that the contractible part — so the muscular part — is situated where there is some space left (GOTTENBOS, 1956, p. 736).

As to the form, build and finer structure of the aponeurosis we find as well a correlation with the architectural or structural scheme. This is in close connection with these qualities of the muscles, mentioned above.

CHAPTER (VII)

PHYLOGENETICAL EXAMINATION OF THE PROJECTIONS, DEEPENINGS AND UNDULATIONS OF THE SURFACE OF THE SKULL IN RELATION TO THE ATTACHMENT OF MUSCLES

The well-known and common branch of phylogenetic research, *i.e.* on the historical-genealogical development of the conservative characters of elements or of the conservative characters of building-stones of the structure, has not much to expect as to our field of interest and research. The reason is that most of the features in our field of interest and research do not show these characters as far as they are typical for larger, more comprising systematic groups, but possess adaptive characters, realized in a limited group of individuals or species only.

On the other hand, if we are interested in the historical-genealogical development of other characters than the conservative ones of building-stones, but become interested in the historical-genealogical development either of bigger elements as *e.g.* functional components, or of functions, or of the relation of form and function, then there is also a way for phylogenetic research in our field of interest. In that field it includes the relations of surface characters of the skull with the attachment of muscles and with the muscles, all three of them in their form, build, finer structure and in their functions and in the relation of form to function. However, this interesting field of research on the historical-genealogical development of these structural-functional units is not very promising, owing to the state of preservation of nearly all fossils.

On the phylogenetic origin of cristae there are two main theories. The increase of the pulling-power exercised by the muscle through the tendons and aponeuroses is considered to be the cause and the fact that many tendinous tissues ossify at the base because of tension or pressure is regarded as an indication of this phylogenetic origin of the cristae. Another theory supposes that these cristae are remnants of bone in a region, where the surroundings have been excavated by the muscles. This latter theory can explain the phylogenetic origin of one of the osseous projections between two fossae or areas of musculous attachment of two muscles lying close to each other. In general they can have the shape of a costa or of a tuber or of a separating or intermediate crista. In one case in *Phalacrocorax carbo sinensis* (Shaw & Nodder), according to DULLEMEIJER, such an intermediate medio-dorsal processus could be seen as a remnant of bone in a region, where the surroundings have been excavated by the muscles (the top of the processus is not occupied by the attachment of a muscle, but sharp lateral edges bear the aponeuroses) (DULLEMEIJER, 1952, pp. 98-99).

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LITERATURE CITED

Assem, J. van den (1952). The relation between muscles and skull structure in the regio branchialis in Squalus acanthias L. I, II. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 55, pp. 656-664, 665-674.

Bams, R. A. (1956). On the relation between the attachment of jaw muscles and the surface of the skull in Podiceps cristatus L., with some notes on the mechanical proporties of this part of the head. Descriptive part. A. I, II, III, IV. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 59, pp. 82-91, 92-101, 248-256, 257-262.

Bas, C. (1954, 1955, 1957). On the relation between the masticatory muscles and the surface of the skull in Ardea cinerea (L.), I, II, III, IV. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 57, pp. 678-685; 58, pp. 101-108, 109-113; 60, pp. 480-485.

Blok, J. W. de (1955, 1956, 1957). On the architecture of the asymmetrical head in Pleuronectes platessa L. I, II, III, IV. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 58, pp. 659-669, 670-678; 59, pp. 240-247; 60, pp. 77-89.

Böker, H. (1935). Einführung in die vergleichende biologische Anatomie der Wirbeltiere. 1. Bd. — Jena, G. Fischer, pp. i-xii, pp. 1-228.

——— (1936). Form und Funktion im Lichte der vergleichenden biologischen Anatomie. — Folia biotheor., Leiden, no. I, pp. 27-41.

——— (1937). Einführung in die vergleichende biologische Anatomie der Wirbeltiere. 2. Bd. Biologische Anatomie der Ernährung. — Jena, G. Fischer, pp. i-xii, pp. 1-258.

Boer, P. J. den (1953). On the correlation between the cervical muscles and the structure of the skull in Phasianus colchicus L. and Perdix perdix L. I, II, III. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 56, pp. 335-345, 455-467, 468-473.

Burggraaf, P. D. (1954). On the correlation between the skull structure and the muscles in the male Phasianus colchicus L. II. The attachment of the musculus adductor mandibulae externus. V. The attachment of the musculus mylohyoideus and of the musculus geniohyoideus. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 57, pp. 292-303, 673-677.

——— & A. Fuchs (1954, 1955). On the correlation between the skull structure and the muscles in the male Phasianus colchicus L. I. General introduction. VII. General considerations. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 57, pp. 286-291; 58, pp. 98-100.

Cool, E. K. P. (1952, 1953). The correlation between muscle attachment and skull structure in Rana esculenta L. I, II, III. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 55, pp. 634-643; 56, pp. 228-236, 237-243.

Cords, E. (1922). Über "funktionslose" Muskeln. — Z. Anat. Entwicklungsgesch., Bd. 65, pp. 254-276.

Davids, J. A. G. (1952). Étude sur les attaches au crâne des muscles de la tête et du cou chez Anas platyrhyncha platyrhyncha (L.). I, II, III. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 55, pp. 81-94, 525-533, 534-540.

DULLEMEIJER, P. (1951, 1952). The correlation between muscle system and skull structure in Phalacrocorax carbo sinensis (Shaw & Nodder). I, II, III, IV. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 54, pp. 247-259, 400-404, 533-536; 55, pp. 95-102.

——— (1956a). The functional morphology of the head of the common viper Vipera berus (L.). Thesis Univ. Leiden, pp. i-viii, 1-111.

——— (1956b). The functional morphology of the head of the common viper Vipera berus (L.). — Archives Néerland. Zoologie, XI, pp. 387-497.

——— (1957). Enige aspecten van de functionele anatomie van Vertebrata. — Vakblad v. Biologen, 37, pp. 1-10.

——— (1958). The mutual structural influence of the elements in a pattern. — Archives Néerl. de Zoologie, Tome XIII, 1. Suppl. (Vol. jubilaire Van der Klaauw), pp. 74-88.

——— (1959). A comparative functional-anatomical study of the heads of some Viperidae. — Morph. Jahrbuch, Bd. 99, pp. 881-985.

FUCHS, A. (1954, 1955). On the correlation between the skull structure and the muscles in the male Phasianus colchicus L. III A. The attachment of the musculus adductor mandibulae posterior and the musculus adductor mandibulae internus. III B. The attachment of the musculus adductor mandibulae posterior and the musculus adductor mandibulae internus. IV. The attachment of the musculus protractor quadrati et pterygoidei and of the musculus depressor mandibulae. VI. Some remarks on a number of ligaments and other connective tissue connections. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 57, pp. 454-461, 462-470, 666-672; 58, pp. 114-120.

GOTTENBOS, J. J. (1956). On the correlation between the muscles and the skull structure in the regio occipitalis and the regio otica in Raja batis L. I, II, III. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 59, pp. 541-553, 723-733, 734-737.

JEUKEN, S. J., M. (1958). Function in biology. — Acta biotheor., Leiden, XIII, pp. 29-46.

KLAAUW, C. J. VAN DER (1941). Skelet van den kop. — In: J. E. W. Ihle, Leerboek der vergelijkende ontleedkunde van de Vertebraten. 2e druk, I, pp. 223-282. — Utrecht, Oosthoek.

——— (1945). Cerebral skull and facial skull. A contribution to the knowledge of skull-structure. — Archives Néerl. de Zoologie, 7 (1946), pp. 16-37.

——— (1947). Skelet van den kop. — In: J. E. W. Ihle, Leerboek der vergelijkende ontleedkunde van de Vertebraten. 3e druk, I, pp. 245-309. — Utrecht, Oosthoek.

——— (1948a). Ecological studies and reviews. IV. Ecological morphology. — Bibliotheca Biotheoretica IV, pars 2, pp. 25-111.

——— (1948b, 1951, 1952). Size and position of the functional components of the skull. A contribution to the knowledge of the architecture of the skull, based on data in the literature. — Archives Néerl. de Zoologie, IX, pp. 1-176, plates I, II; pp. 177-368, plates III-VIII; pp. 369-559.

——— (1956). Schedelrelief en spieraanhechting. — Verslag gewone verg. Afd. Natuurkunde 65, pp. 73-77.

LAKJER, T. (1926). Studien über die Trigeminus-versorgte Kaumuskulatur der Sauropsiden. Hrsg. von A. Luther und C. Wesenberg-Lund. — Kopenhagen, Reitzell, pp. 1-155.

MANGER CATS, V. (1951). On the correlation between the muscles and the skull structure in the regio occipitalis and the regio otica of some Squaliformes. I, II. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 54, pp. 191-201, 296-300.

MANGER CATS — KUENEN, CH. S. W. (1961). Casque and bill of Rhinoplax vigil (Forst.) in connection with the architecture of the skull. — Verh. Kon. Ned. Akademie van Wetenschappen, afd. Natuurkunde, 2e reeks, deel 53, no. 3, pp. 1-51.

MOLLIER, G. (1937). Beziehungen zwischen Form und Funktion der Sehnen im Muskel-Sehnen-Knochen-System. — Gegenbaurs Morphol. Jahrbuch, Bd. 79, pp. 161-199.

ROOTH, J. (1953). On the correlation between the jaw muscles and the structure of the skull in Columba palumbus palumbus L. I, II. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 56, pp. 251-259, 260-264.

SARKAR, SAKTI PRASAD (1960). A study of functional morphology of the head of an Indian puffer fish, Sphaeroides oblongus (Bloch). Diss. Fac. Wis.-Nat.k., Univ. Leiden. — Rijswijk, 119 pp.

VAART, H. R. VAN DER (1958). Some remarks on the application of engineering science to biology. — Archives Néerl. de Zoologie, Tome XIII, 1. Suppl. (Vol. jubilaire Van der Klaauw), pp. 146-166.

VENDELOO, N. H. VAN (1953). On the correlation between the masticatory muscles and the skull structure in the muskrat, Ondatra zibethica (L.). I, II. — Proceed. Kon. Nederl. Akad., Amsterdam, Series C, 56, pp. 116-127, 265-277.

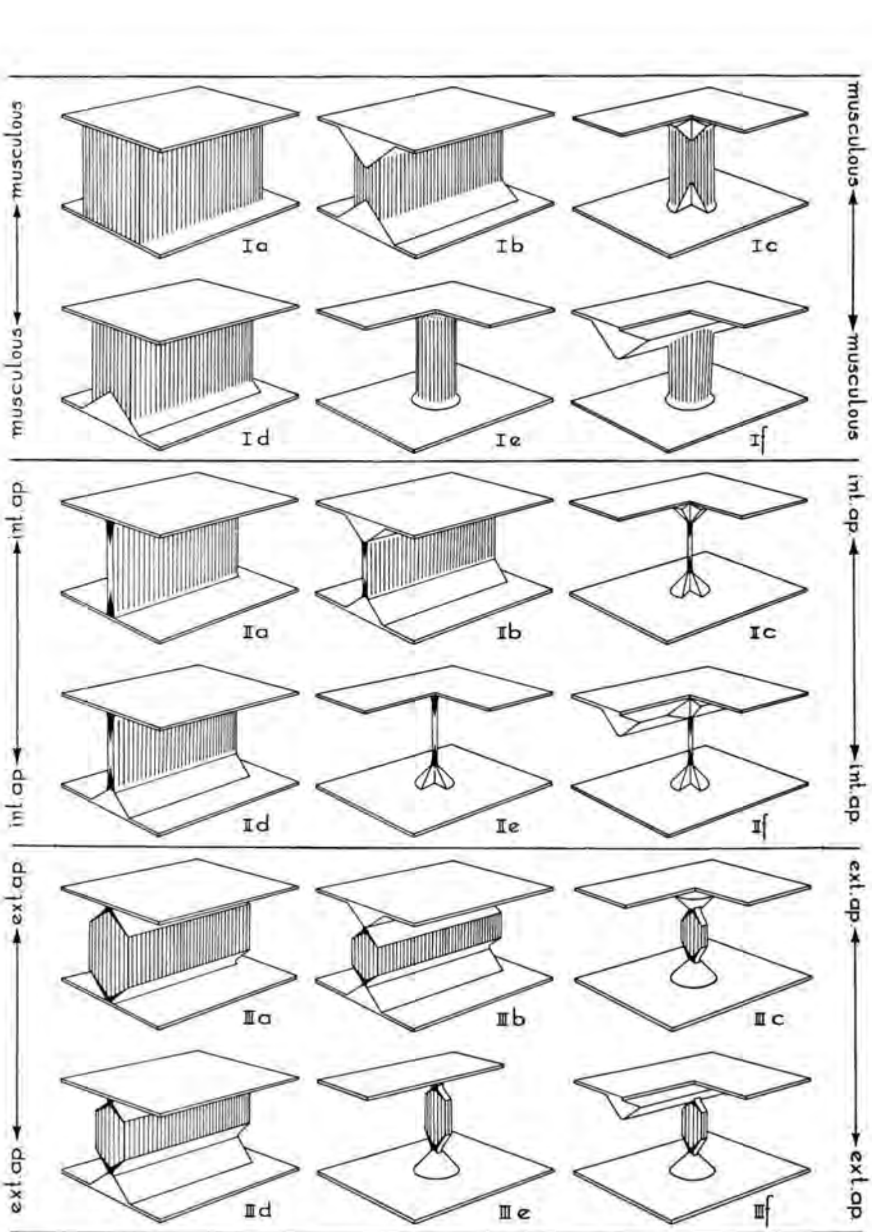
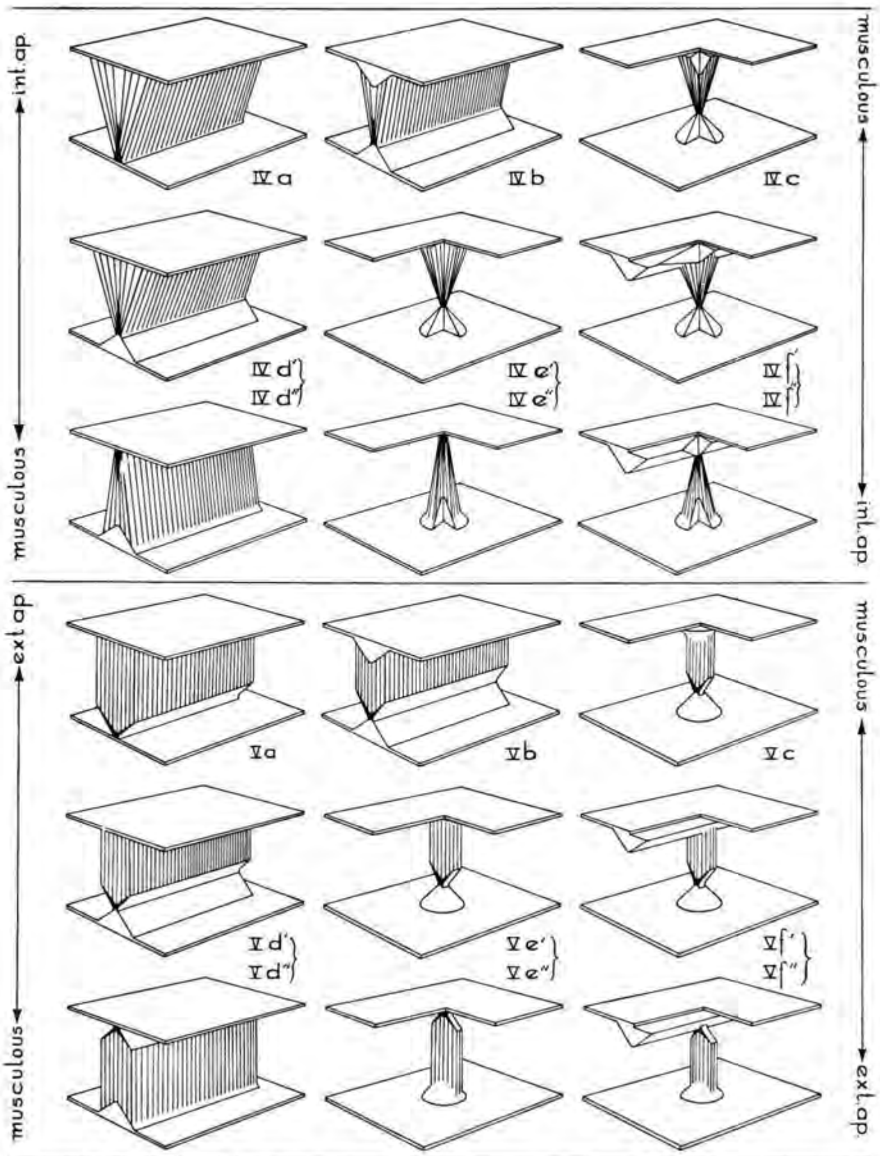


PLATE 1. See text on pp. 20, 21, 31, 32 and 82.



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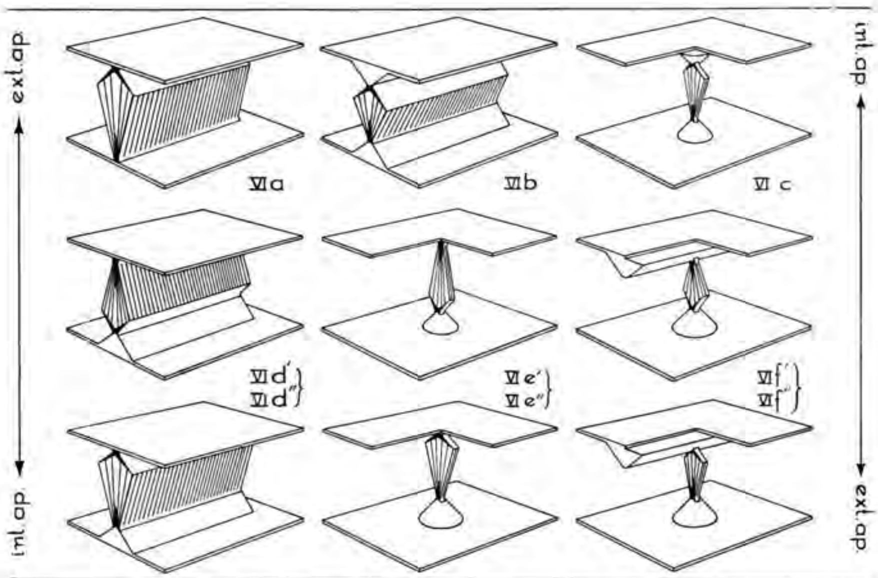

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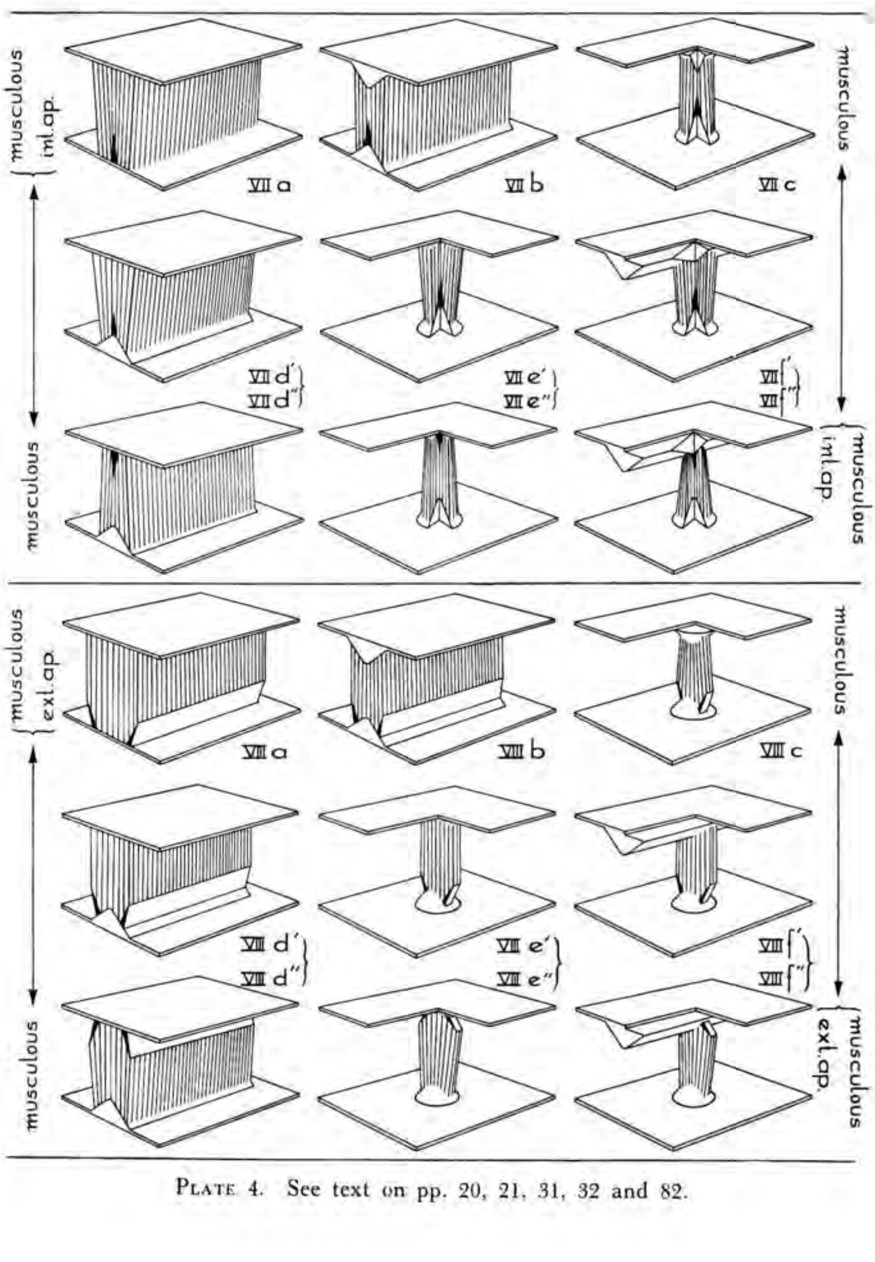

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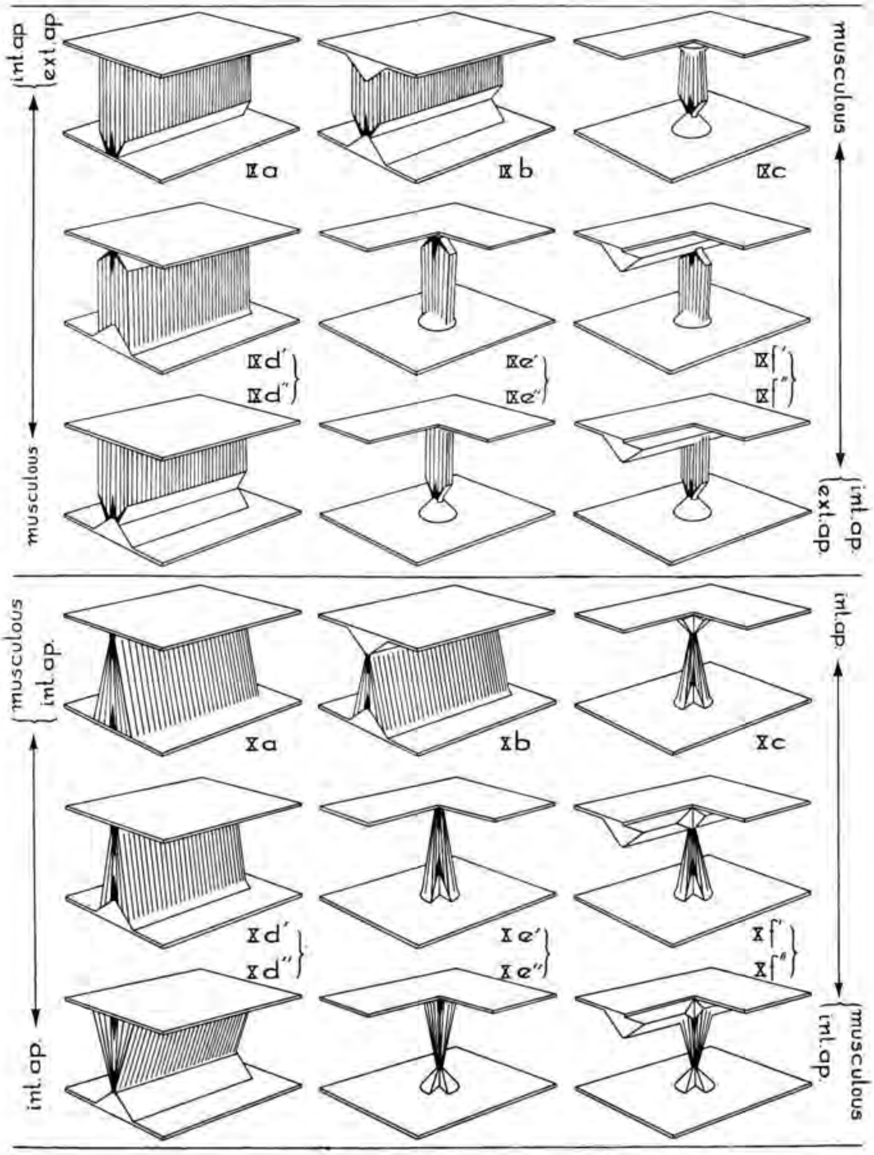

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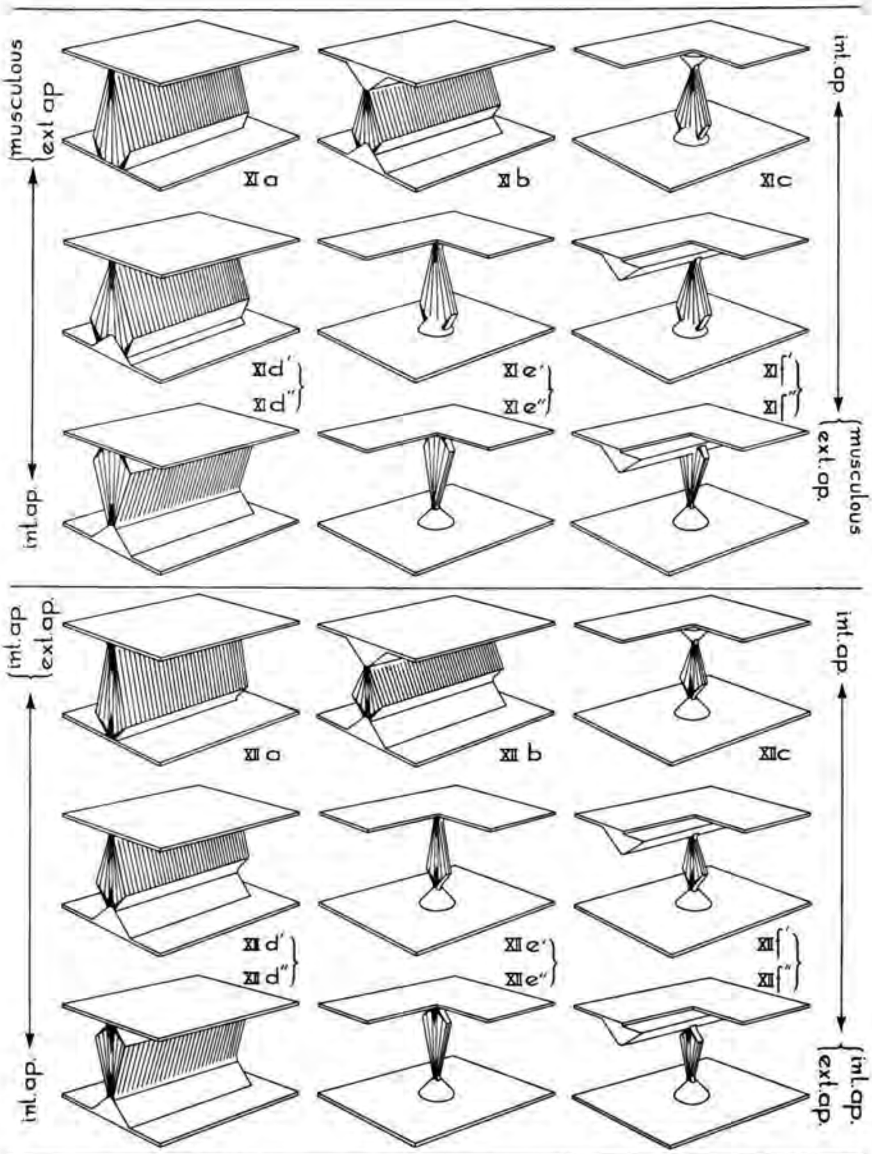

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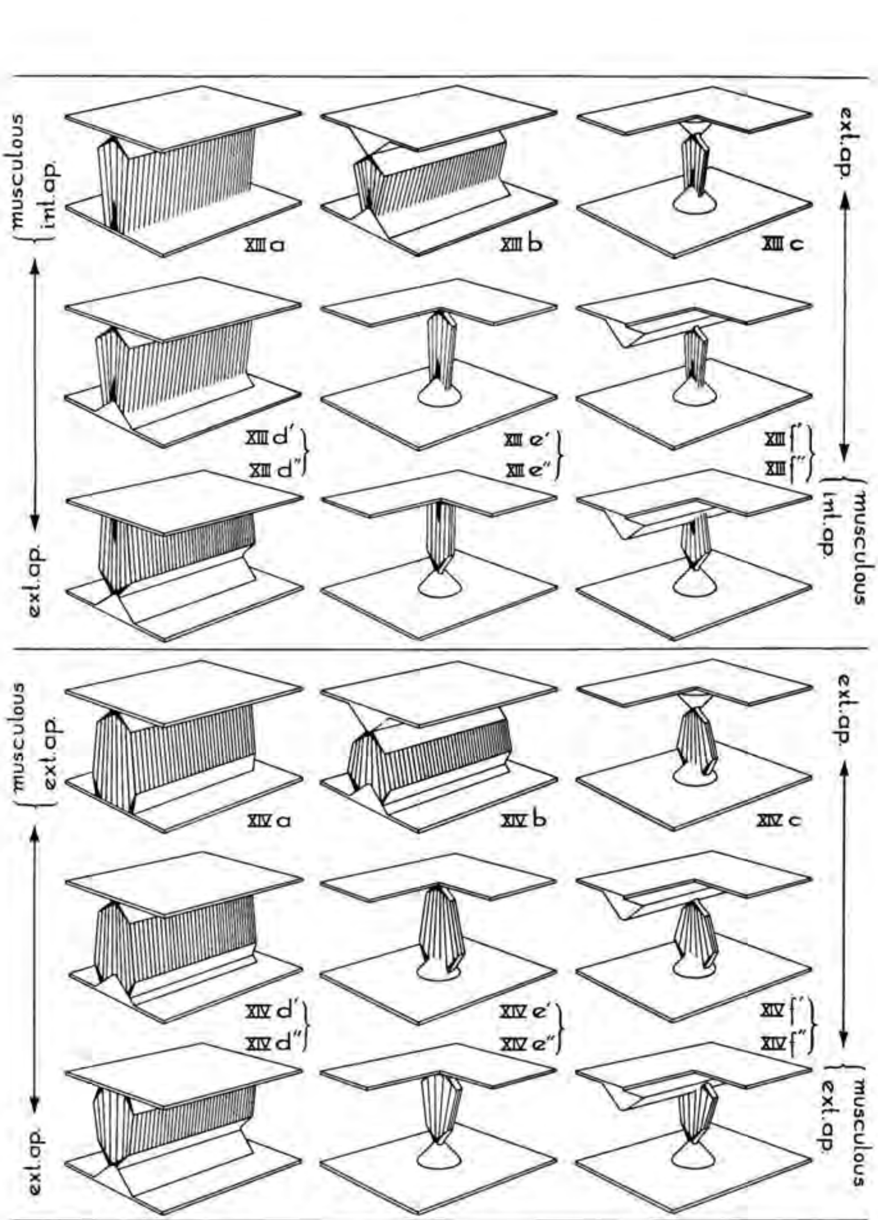

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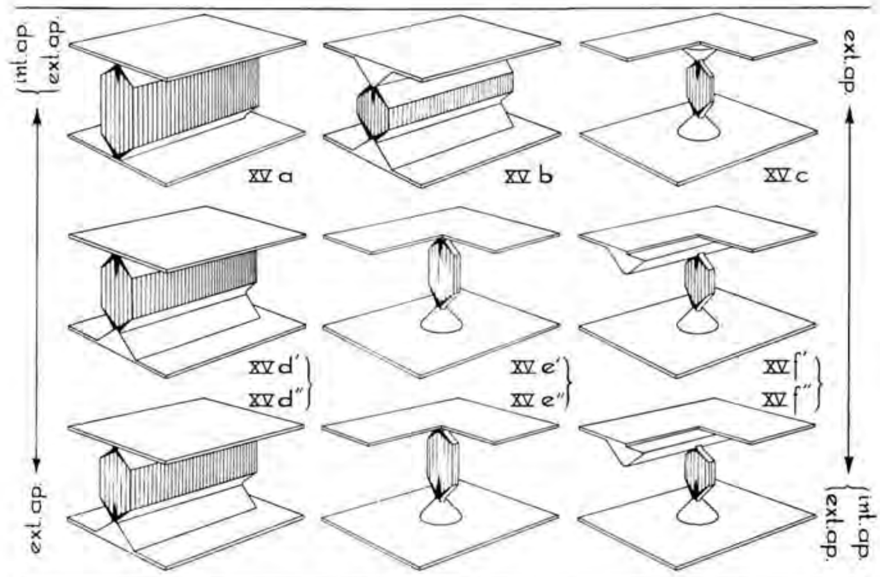

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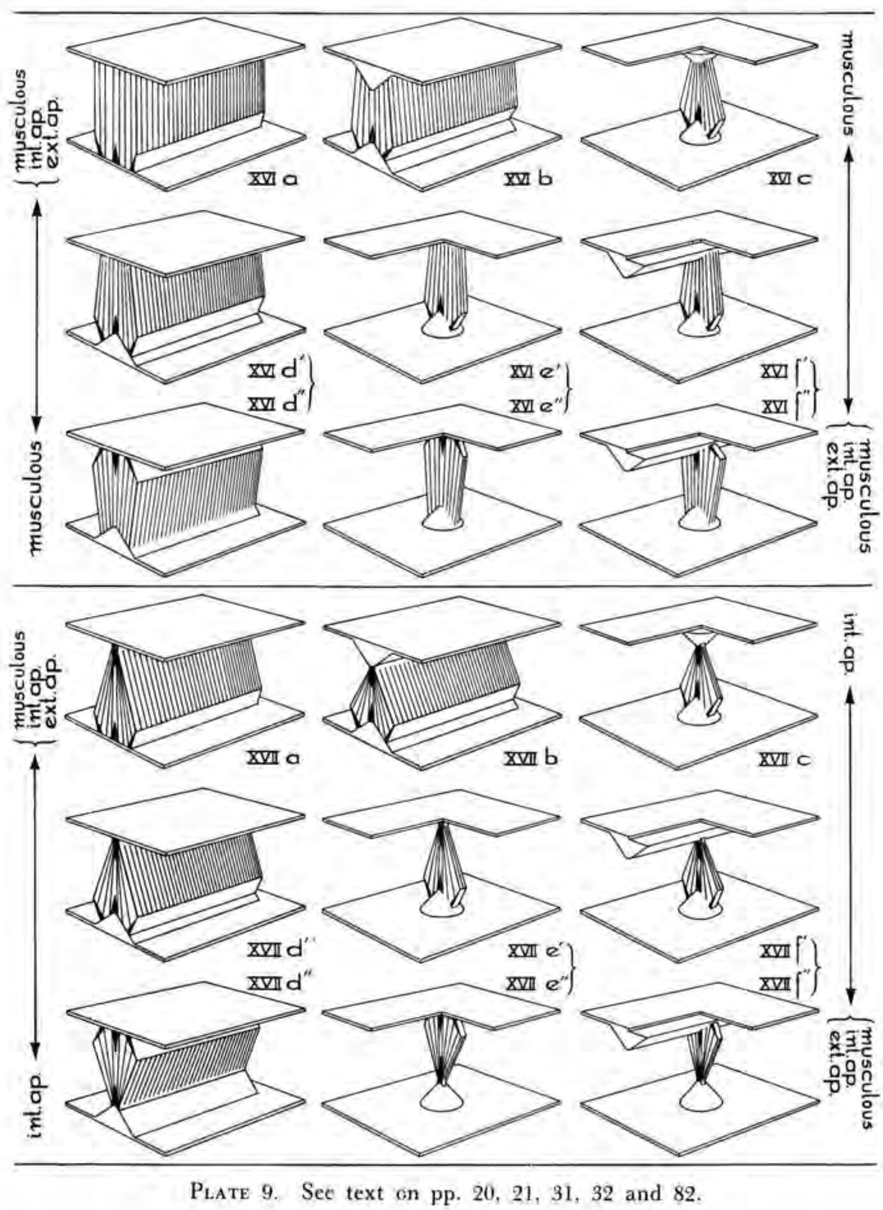

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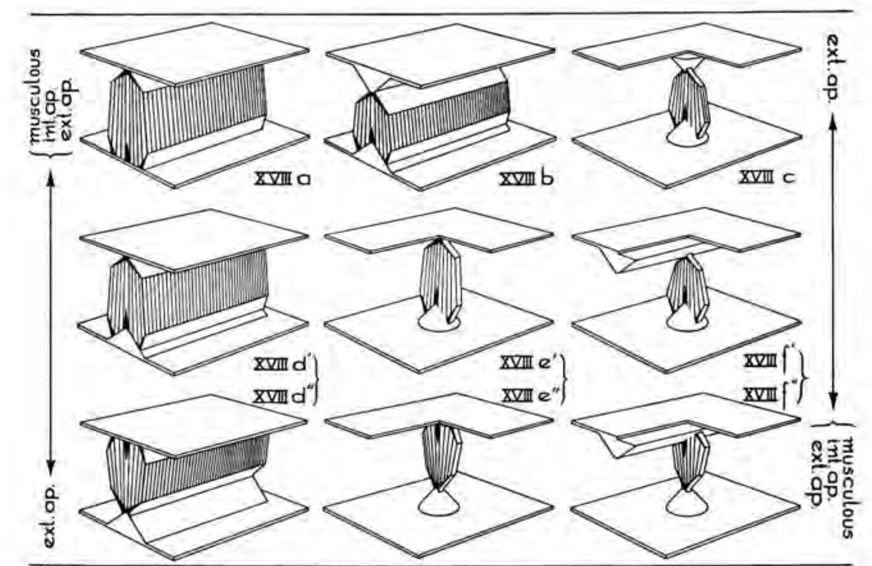
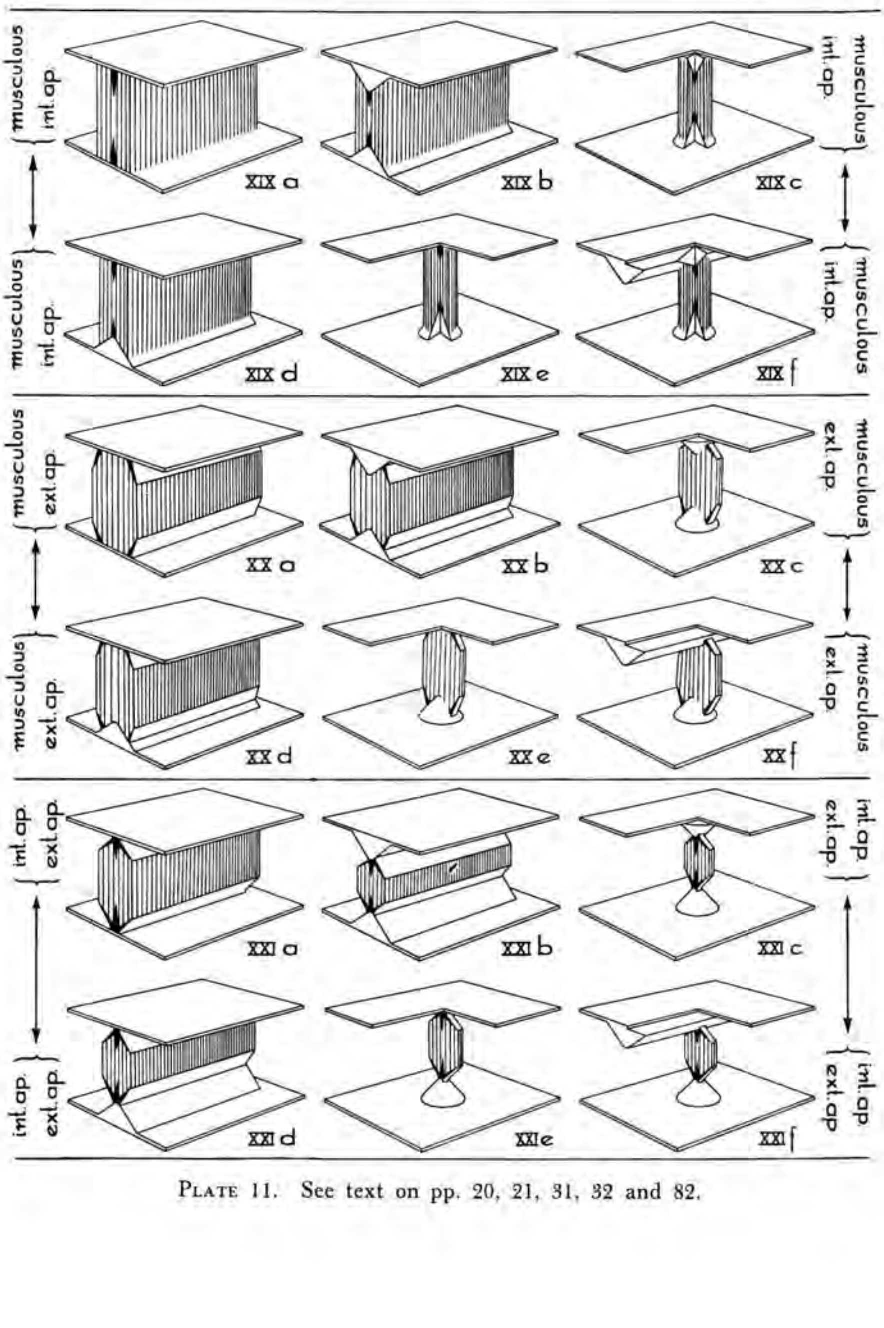


PLATE 10. See text on pp. 20, 21, 31, 32 and 82.



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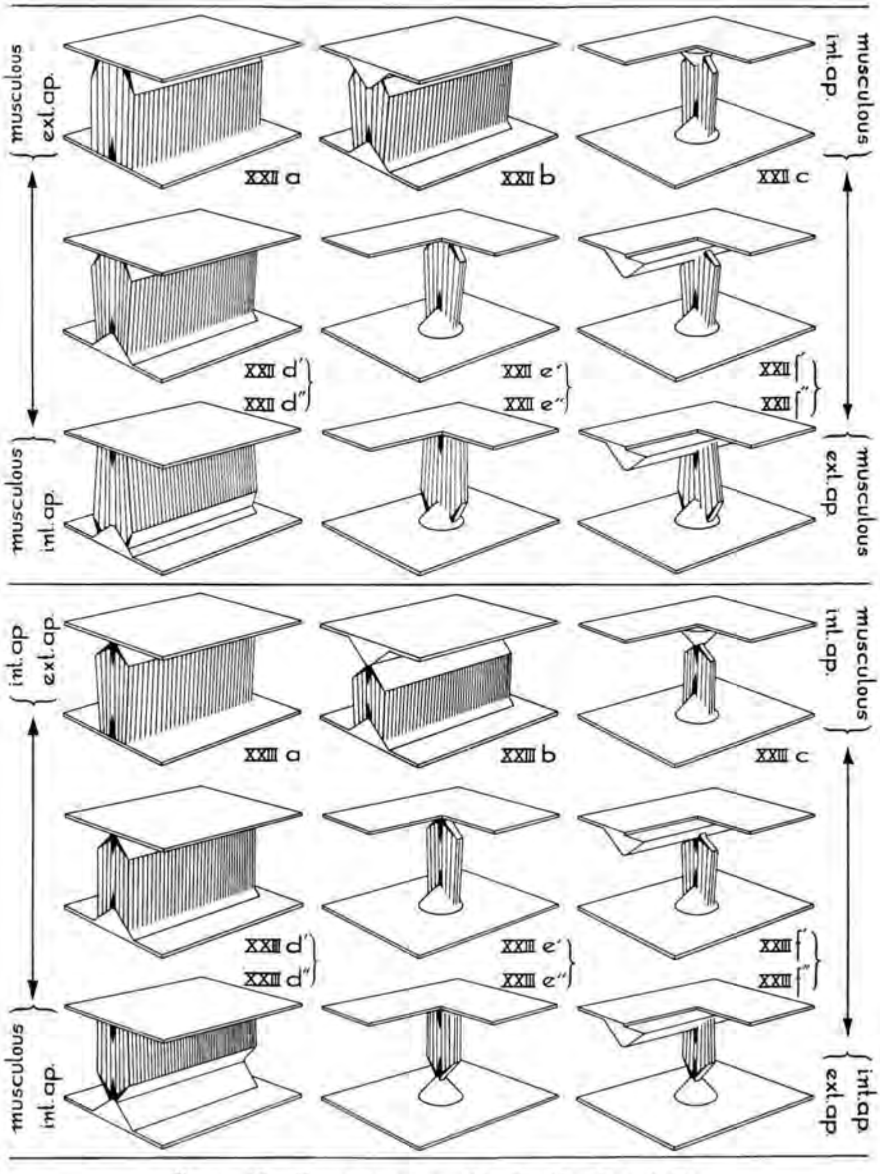

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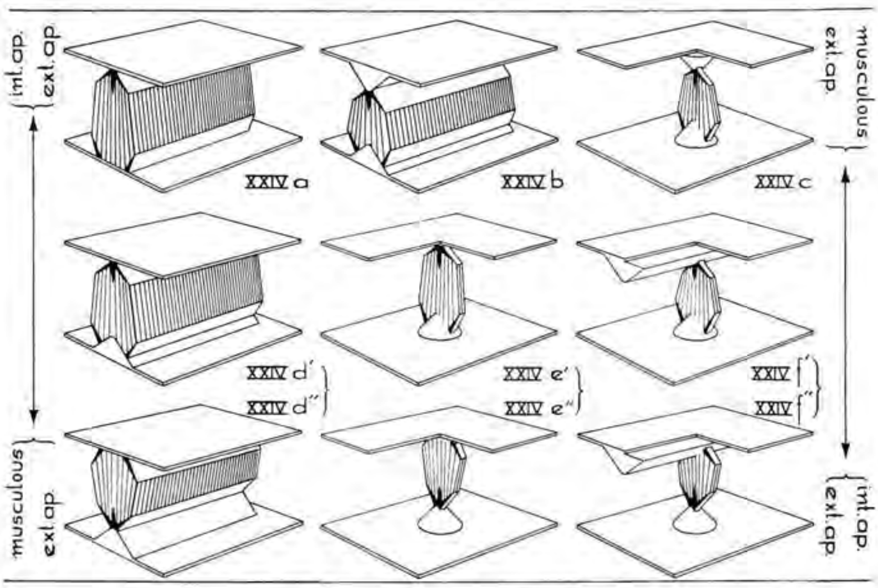

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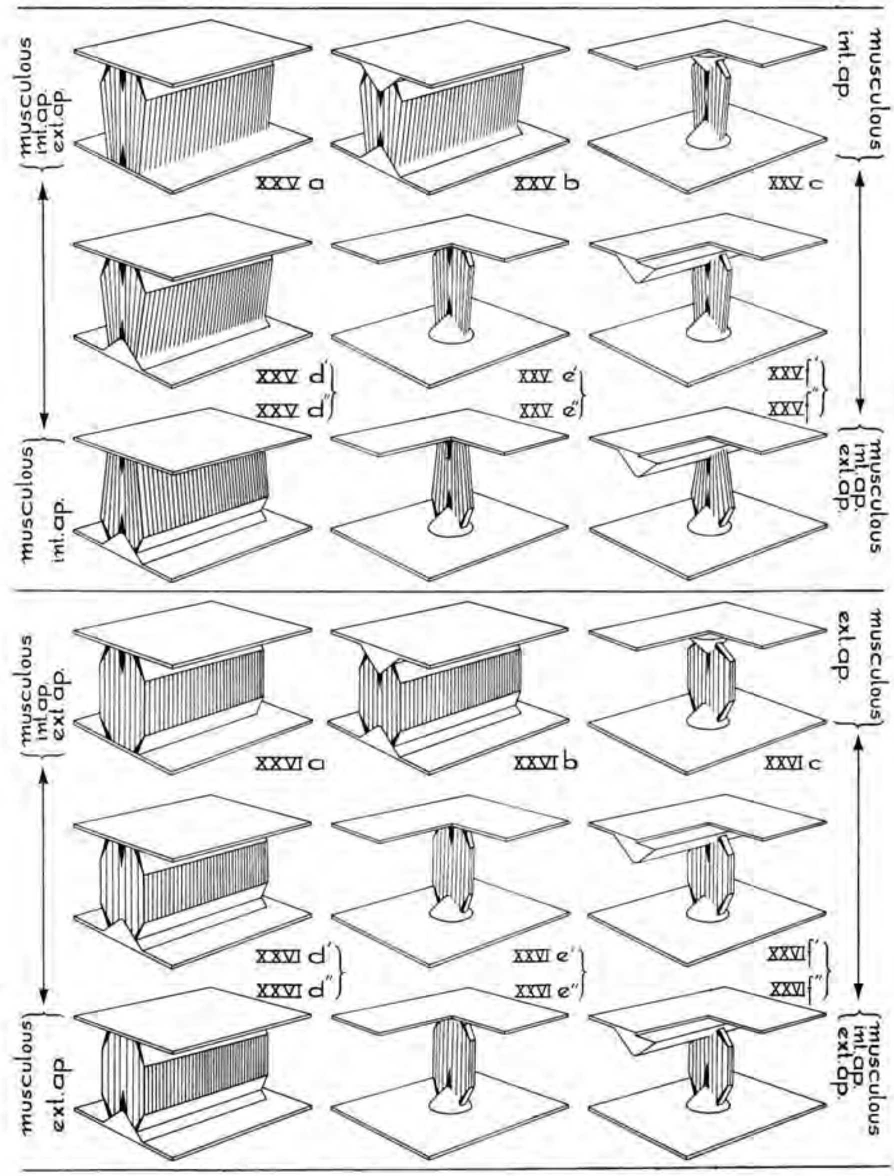

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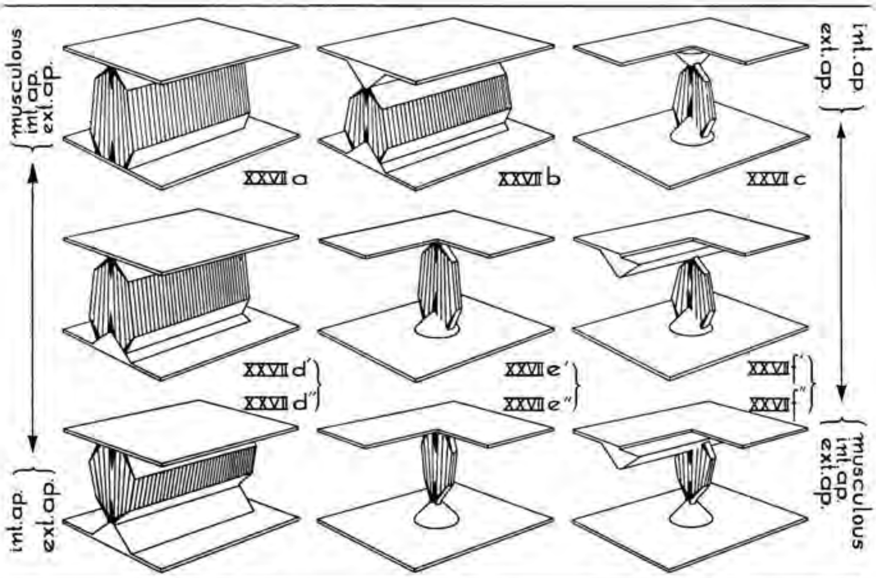

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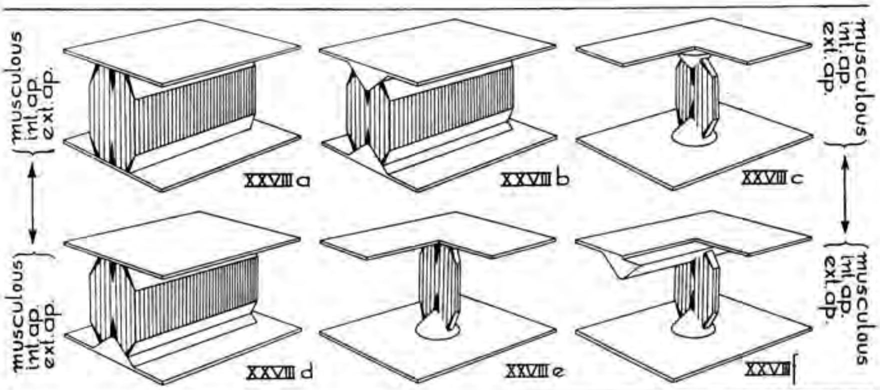

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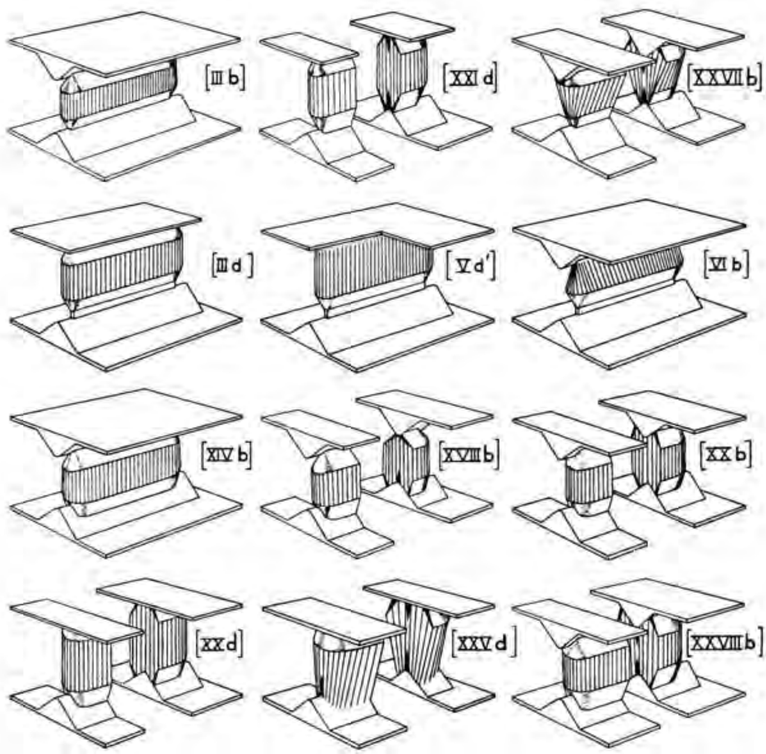

Plate 17. See text on pp. 22, 31 and 32. Read XXV d′ instead of XXV d.

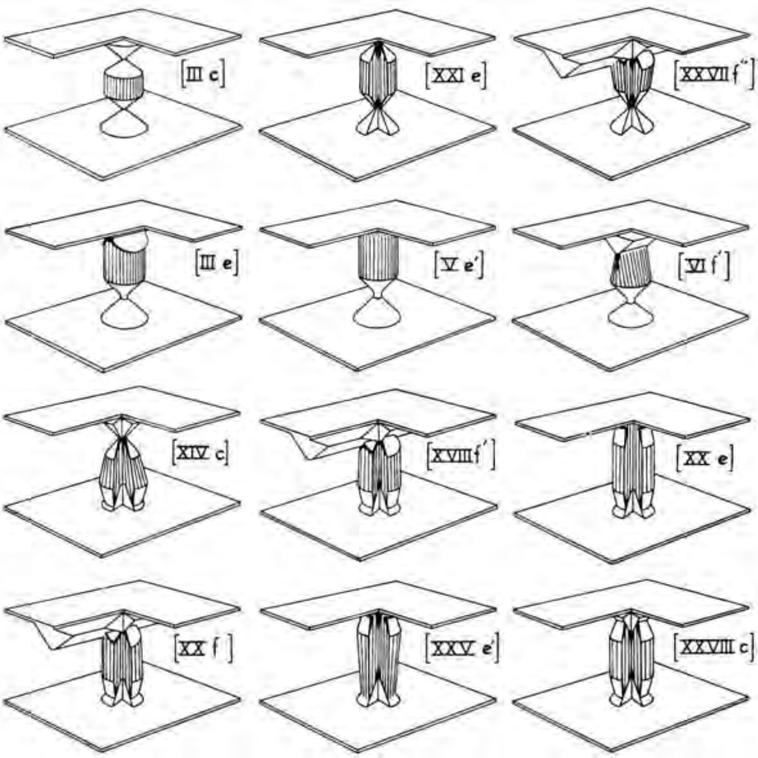

PLATE 18. See text on pp. 22, 31 and 32.

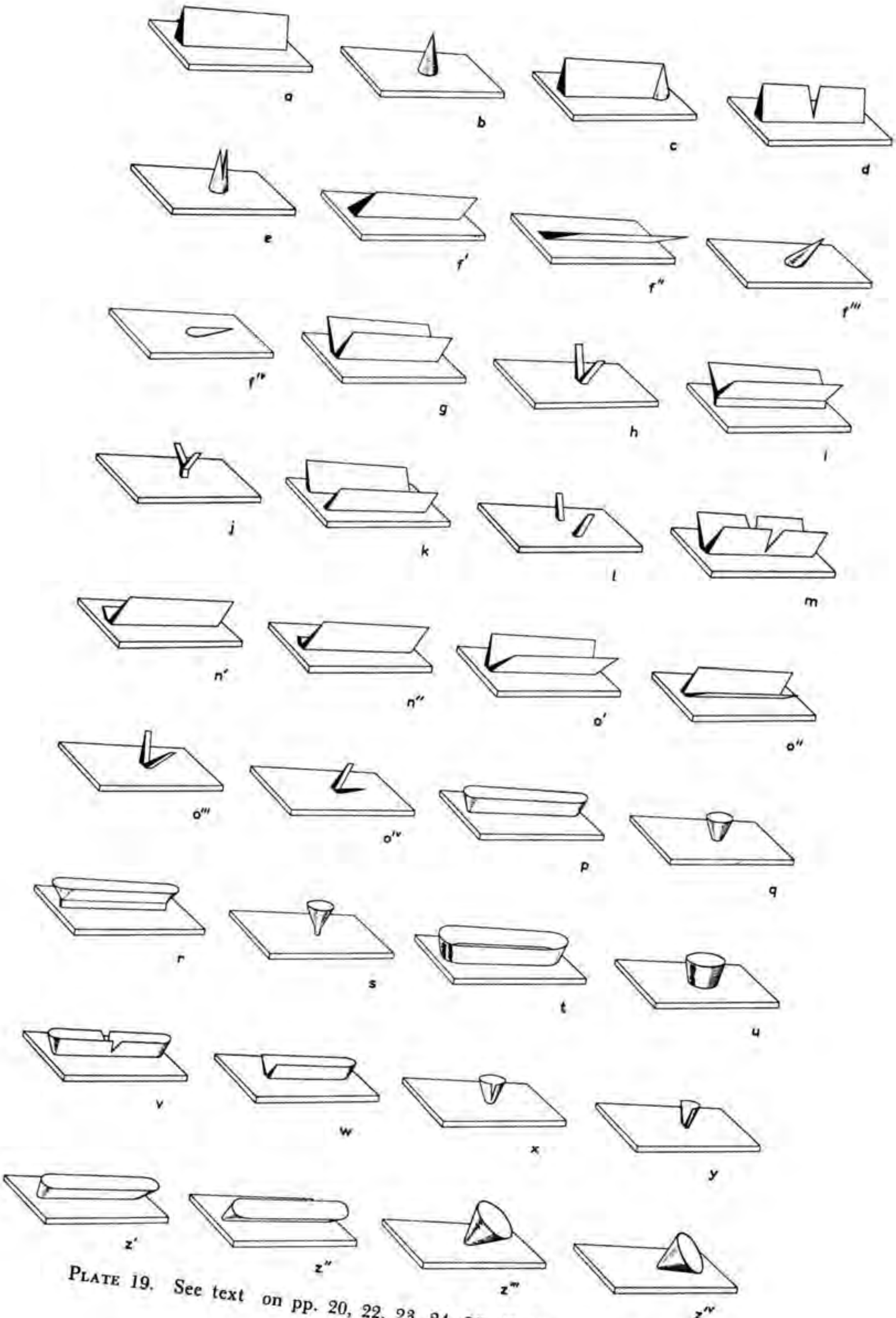

PLATE 19. See text on pp. 20, 22, 23, 24, 25, 27, 28, 30 and 34.

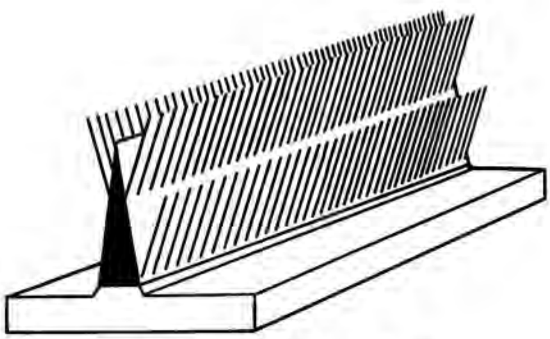

PLATE 20. See text on p. 33.

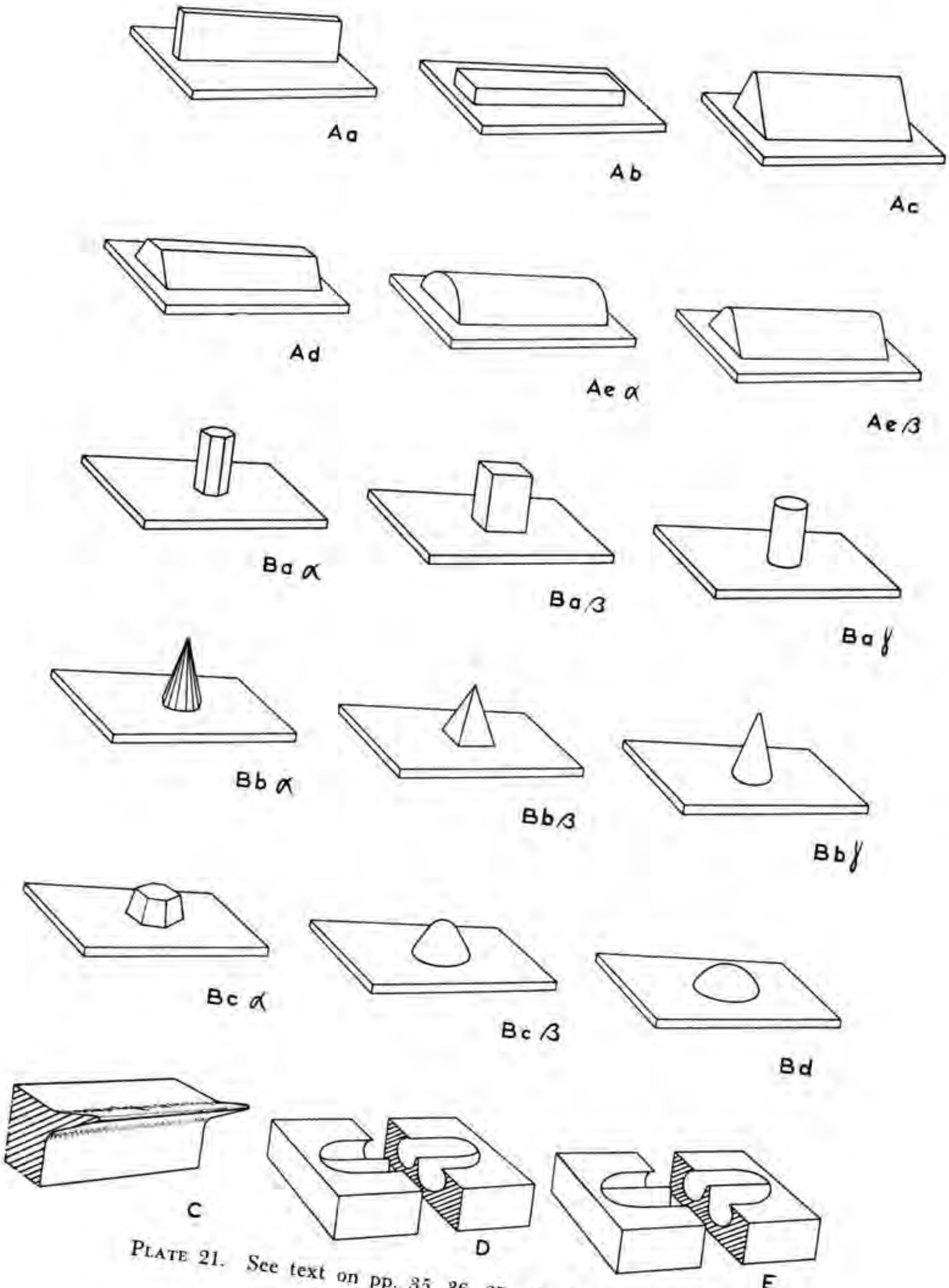

Plate 21. See text on pp. 35, 36, 37, 38, 39 and 40.

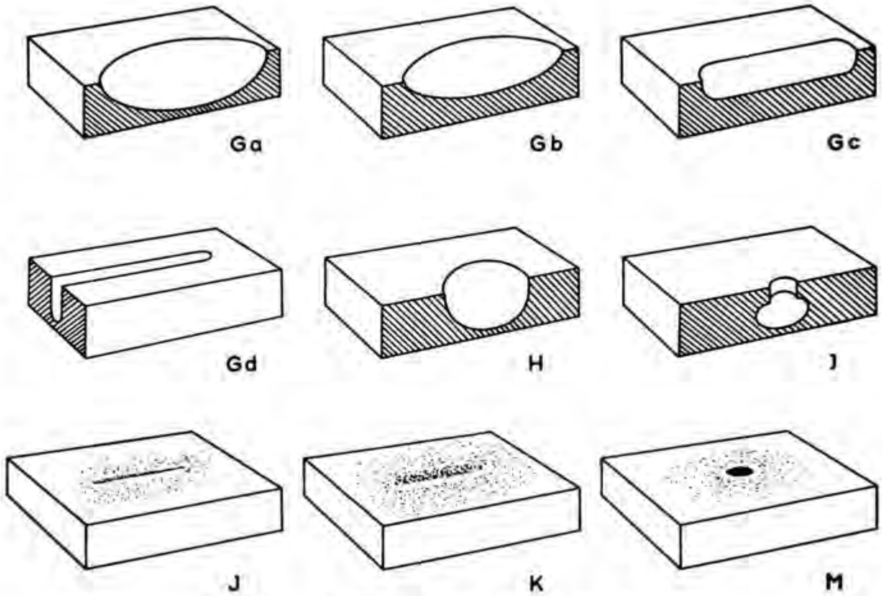

PLATE 22. See text on pp. 30, 41, 42 and 43.

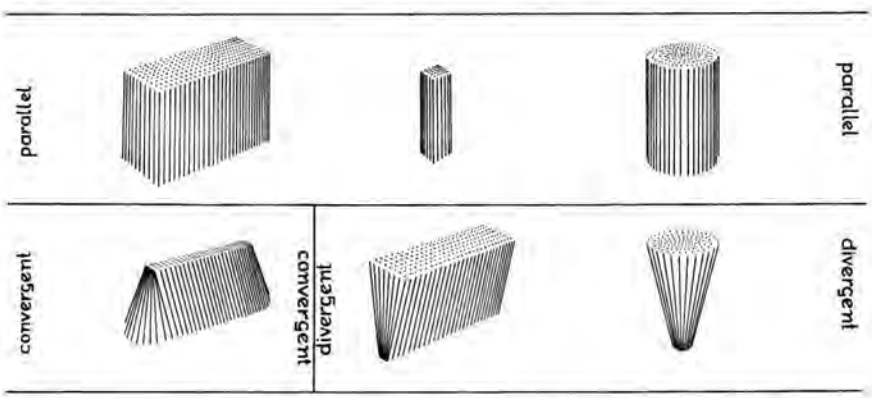

PLATE 23. See text on p. 70.

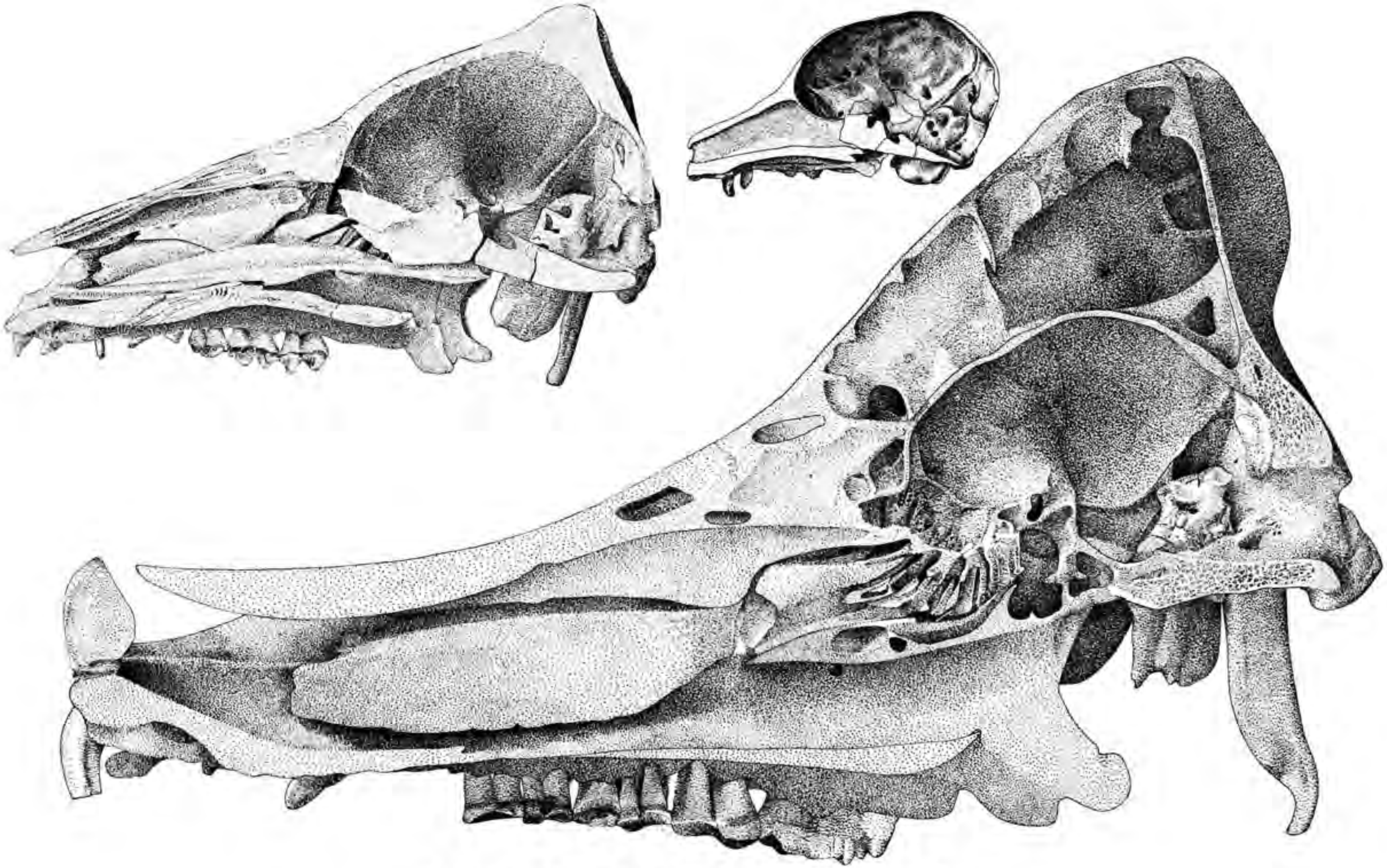

PLATE 24. See text on pp. 196 and 244. 0.6 × nat. size.

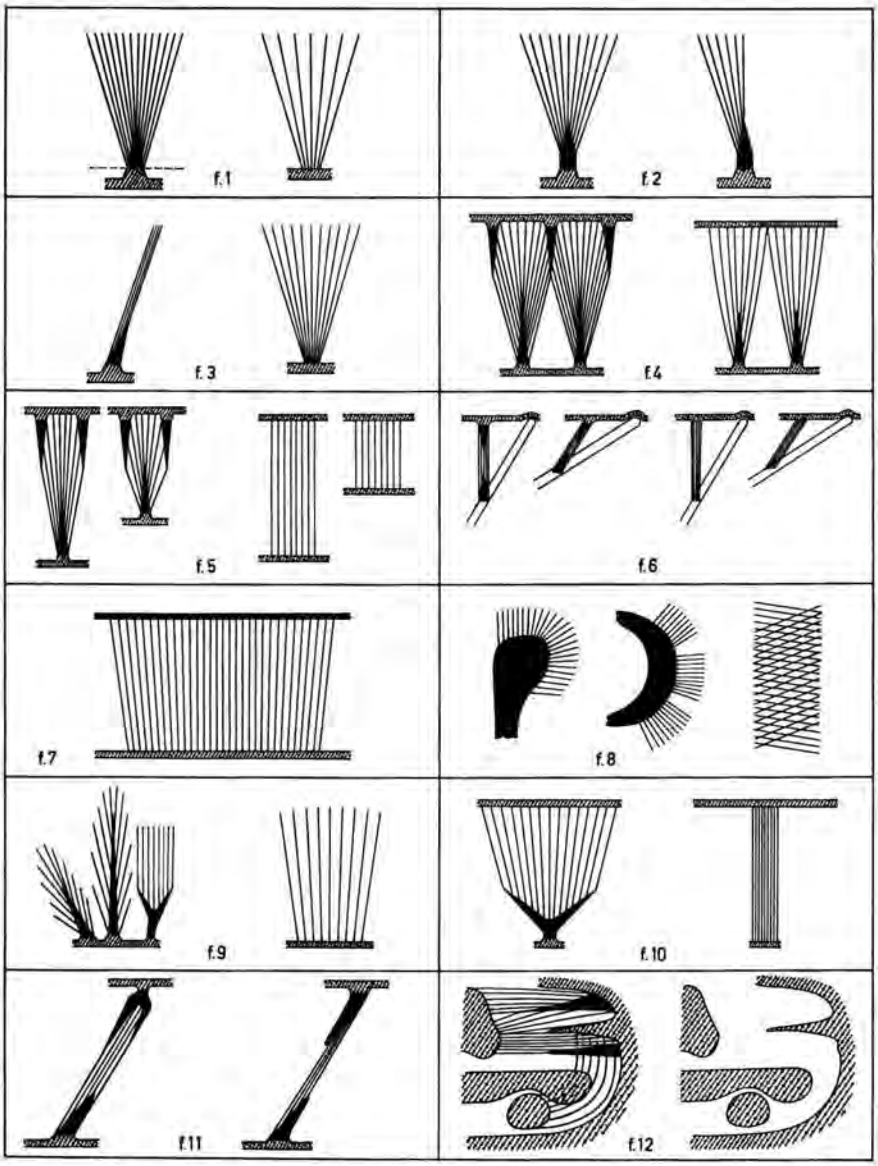

PLATE 25, illustrating function 1-12. See text on pp. 205-210.

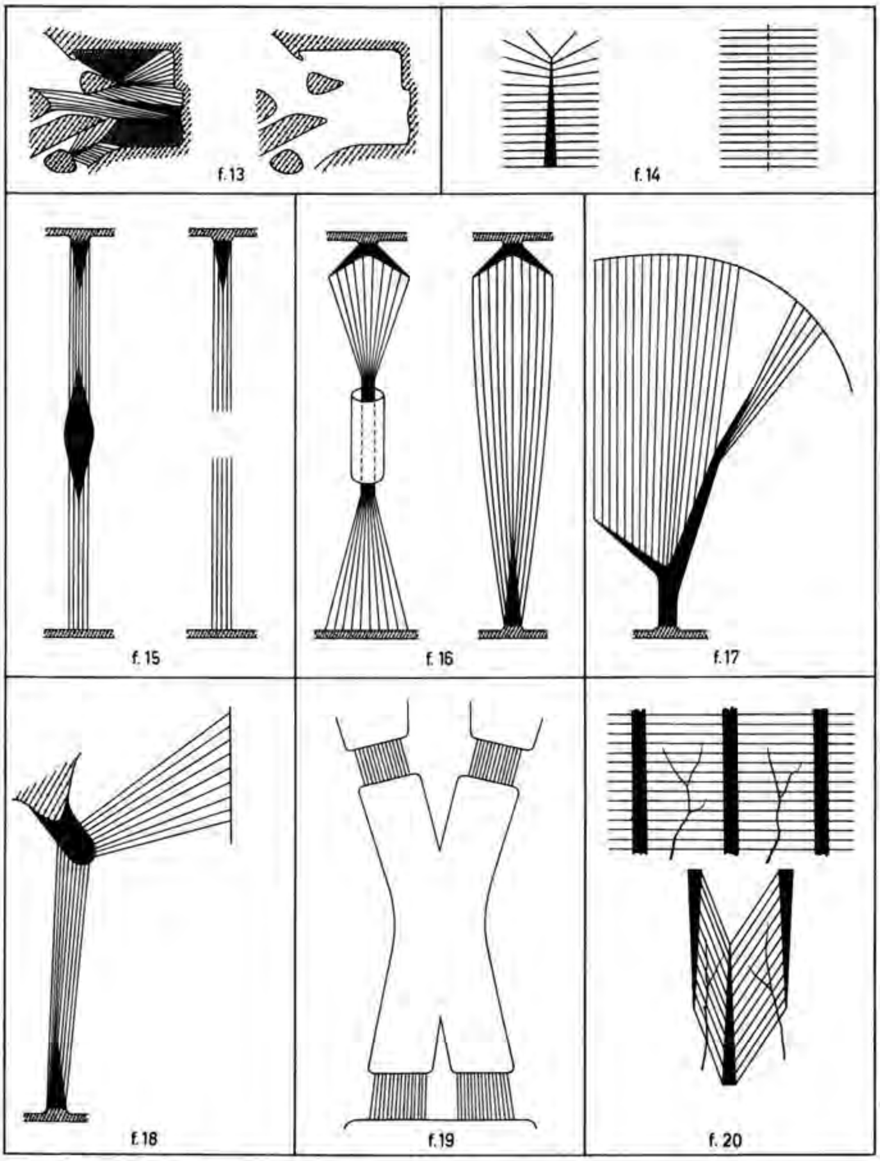

PLATE 26, illustrating function 13-20. See text on pp. 205, 210-212.